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ANÆSTHETICS

PLATE I.

Method of spinal injection (see p. 504). If these figures are looked at through a stereoscope, the exact position of the needle is well seen. (Sir J. Mackenzie Davidson has kindly taken these photographs.)

Frontispiece]

ANÆSTHETICS

THEIR

USES AND ADMINISTRATION

BY

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PREFACE TO THE SIXTH EDITION.

THE whole of the book has been revised and some sections have been rewritten. The experience gained in the Great War has modified and in many ways enlarged our knowledge of anæsthetics. This has made it necessary to recast portions of the book, and to add a section on Shock in so far as that condition comes within the purview of the anæsthetist. The writer is fully conscious that so wide and complicated a subject cannot be adequately treated in the number of pages devoted to it, but he hopes that a brief outline of the theories of Shock, and more especially of its treatment before, during, and after the administration of an anæsthetic, may prove of value at least as a guide to research and as an incentive to thought. Germane to this is the new section upon Hæmorrhage. This includes references to many forms of danger through severe hæmorrhage. It is hoped that, when the anæsthetist has his mind stored with such possible sources of danger, he will be better able to understand the problems presented by such cases, and so be in a position to apply prophylaxis and treatment.

The chapter dealing with Complications and Dangers has been enlarged and its arrangement modified. It now includes Shock and the little understood subject of Angio-neurotic Œdema, and the treatment of hæmorrhage before and under anæsthesia. A fuller account of Massage of the Heart is now presented, since that plan of treatment has proved more successful than it was a few years ago. The Posture of the patient, important in all cases, whether they are normal or involve special dangers, has been fully discussed. In this instance, as indeed in others, although a subject is dealt with cursorily in the various chapters dealing with each anæsthetic, it has been considered advisable to reiterate descrip-

tions and rules of procedure so as to focus them in one portion of the book. It has been felt that, even at the risk of some repetition, this plan enables a reader to find what he requires without a tedious reference to paragraphs scattered throughout many sections of the book.

Dealing with ether, the writer has recast the whole chapter, and added a notice of the importance of the method of giving warmed vapours. The value of such accepted methods as intra-pharyngeal, and especially intratracheal, insufflation of ether has been fully proved, and so these have been more fully discussed. To Dr. Shipway the writer owes much for his help and advice about this section of the book.

For many cases of major surgery, the use of the nitrous oxide and oxygen mixture administered after alkaloids has been shown to be of great value. Even if its greater safety as compared with ether has yet to be substantiated, there is little doubt that, in the hands of not a few workers, the results obtained have established the claim that it is one of the best methods in cases of shock and cognate states.

The Anoci-association plan has been largely adopted either in principle or in full detail, hence more space has been allotted to it ; and Dr. Crile's views have been discussed at some length. Dr. Goodman Levy's work on ventricular fibrillation is also reviewed.

As will be seen if the book is carefully read, the writer has ventured to repeat his views upon the advisability of avoiding a routine choice of anæsthetics. There are many good methods : some are valuable in individual cases, dangerous in others. To obtain uniform success the anæsthetist must be familiar with all, and be capable of fitting the appropriate anæsthetic and best method to the exigencies of any particular patient or operation. Otherwise failure or discredit of a method ensues.

The chapter concerned with Local Analgesia and Spinal Anæs-thesia has been considerably enlarged. The section upon Local Analgesia has been written sufficiently fully to enable the reader to understand the principles involved, and to deal with all but

the most complicated operations which can be performed during its use. The portion on Dental Analgesia, it is hoped, will prove adequate for dental operators, as it goes with some detail into the subject. It is obvious, however, that practice and experience are absolutely necessary before uniformly satisfactory results can be obtained.

Spinal anæsthesia has now become more firmly established as a desirable method in certain cases; its advantages have been proved and its limitations more clearly defined, so that the description of it has been rewritten. Mr. Barker's valuable work has been retained, additions and corrections having been supplied, when needed, from material supplied by Dr. Rood and others. The kindred subjects of paravertebral, parasacral, and sacral anæsthesia have also been included in the present edition.

The writer has attempted to give the views of all workers as fairly and fully as possible, and has included descriptions of various new forms of apparatus.

Many friends have given material aid, and the author desires to express his thanks to Sir Charles Ballance, K.C.M.G., Dr. Blomfield, Mr. Boyle, Dr. Cowell, Professor Leonard Hill, Mr. Hirsch, Mr. John Malcolm, Professor MacWilliam, Dr. Geoffrey Marshall, Professor Waller, and many others. Mr. C. H. Hampshire, B.Sc., F.I.C., has kindly revised the pharmacology of the book, and Dr. Beresford Kingsford has been so good as to read the proof sheets. Professor Bayliss has materially assisted the writer by supplying much valuable information. Various owners of blocks for illustration have again lent these, and to them the author tenders his thanks.

DUDLEY W. BUXTON.

September 1920.

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INTRODUCTION.

THE experience gained in teaching the principles underlying the safe use of anæsthetics in surgical practice has led the writer to believe that the following preliminary remarks may prove of service.

The first essential of the anæsthetist is a full appreciation of his responsibility when administering an anæsthetic. The timid and the reckless are equally dangerous, the one because he has no faith in his knowledge, the other because he has never realised that his skill and knowledge alone stand between his patient and peril, possibly death.

The apparatus to be employed should be carefully examined before use, and the anæsthetic should be tested by smelling before being placed in the inhaler or dropped on the mask. The armamentarium of the anæsthetist should consist of the inhaler selected, an adequate quantity of the anæsthetic which has been chosen as most suitable for the patient, and, when the particulars of the case are not known, an alternative anæsthetic and apparatus should be at hand, also a gag, tongue forceps, gauze folded to serve as swobs with holders, a mouth-opener, tracheotomy instruments and intubation tubes, as well as a solution of strychnine, pituitary extract, morphine, atropine, digitaline, together with a hypodermic syringe, should be in readiness. In cases in which special dangers are apprehended additional aids may be required, such as a cylinder of oxygen, and a bellows fitted with india-rubber tubing, for pulmonary perflation. All instruments, rubber bags, and face-pieces must be carefully and thoroughly cleansed before and immediately after use. Complete sterilisation when possible should be carried out. In cold weather the rubber of tubes and face-pieces should be rendered pliant by warming in hot water.

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The terminology of the subject may be referred to in this place. Narcosis is used to connote the effects upon the patient caused by his blood and tissues being brought under the influence of alkaloidal bodies, such as morphine, and of anæsthetics, such as choloroform. It is obvious that these effects must vary according to the amount and strength of the agents employed, and so they are grouped into "degrees of narcosis." Five of such degrees were recognised by Snow, and although the division is empirical, this division is useful, and is adopted in the present book. The French physiologists speak of three degrees of narcosis, since they consider the deeper narcosis following anæsthesia is toxæmic. The five degrees of Snow embrace the effects following the initial action of an anæsthetic up to the final catastrophe—death. Practical anæsthesia is concerned with the first three; the last of these is true surgical anæsthesia, which is a definite state, and cannot be spoken of as light or deep, since light anæsthesia really means the antecedent (second) degree of narcosis, while deep anæsthesia means a more profound narcosis (fourth degree) than exists in the state of anæsthesia (third degree). It is perfectly true that the depth of narcosis at the commencement of the third degree is less than at the end; but, to avoid confusion, this variation in depth should be associated with the terms "narcosis," while anæsthesia should be reserved to denote merely a condition in which the patient is unconscious of pain and ideationally unaffected by stimulation of sensory areas.

Analgesia should be restricted to the condition which is present when, although the patient is conscious, yet, owing to the local action of some drug, the sensory nerves or sensory nerve-roots of a particular area do not conduct sensory stimulation to his brain, so that the patient experiences no pain when trauma is inflicted on the area rendered analgesic. Dr. Gwathmey has introduced the phrase "general analgesia," by which he means the obtunding of sensation consequent upon swallowing narcotics such as chloroform, ether, and so on. It is best, however, to regard this state as anæsthesia, since it is probably due to action upon the central nervous system. Spinal analgesia, often termed anæsthesia, is merely a form of regional analgesia.

Nomenclature of apparatus and methods.—The terms "closed," "open," "semi-open," "semi-closed," when applied to ethyl chloride, ether, and chloroform, are not strictly accurate, but, as they have gained currency, it has appeared best to adopt them

rather than to introduce new terms. By " open," as applied to masks, is meant a method which involves the use of a frame or mask, covered with some open meshed material, such as gauze, domett or lint. If any air-tight covering is added, such as thin rubber, a rolled towel, oiled silk, or oiled paper, the method becomes a " semi-open," although it is in some instances a closed method to all intents and purposes.

" Closed " methods are understood to be those in which a cone or inhaler is used, and the patient inspires through tubes and at times breathes to and fro into a closed bag.

Inhalers are conveniently described as " dosimetric " when they enable the anæsthetist to control accurately the strength of the vapour presented to the patient. The supply may be aspirated by the patient's own inspiratory effort—and this is the " draw-over " system ; or an atmosphere may be pumped by a motor into a face-piece or bag from which the patient breathes—and this is the " plenum " system. Two methods are commonly pursued in supplying the anæsthetic to open masks, " dropping," when it is allowed to fall drop by drop, and douching, when it is poured on the mask a drachm or more at a time—this is the " douche " method.

CHAPTER I.

HISTORICAL.

MEANS for producing surgical anæsthesia were practically unknown until Wells introduced nitrous oxide, Crawford Long employed ether, and Simpson chloroform. With the first employment of these agents commences the history of artificial anæsthesia, although from very early times attempts were made to obtain insensibility during surgical operations.

Nepenthes, or sedative draughts to relieve severe pain, are mentioned in the "Odyssey," Helen seeking to "drown all sense of woe" and to assuage the sufferings of Menelaus by such means. In Egypt, cannabis indica, the modern hashish, and other drugs, were similarly used. The " wine of the condemned " spoken of by the seer Amos was held by Simpson to have been derived from cannabis indica. Both among the Chinese and the Jews narcotics were given to criminals to alleviate the agonies of their death struggles. The Assyrians and Chinese seem to have employed various drugs with a view to relieve the anguish of wounds and of such rough surgery as was practised among them. Dr. Dudgeon of Pekin, however, gives little credence to the somewhat exaggerated narratives which have appeared concerning the extent to which anæsthesia was practised among the Chinese.

Opium, cannabis indica, carbon dioxide, and deadly nightshade were advocated in various forms to achieve this object. Pliny and Dioscorides describe several methods in vogue among the Romans and other nations for benumbing parts subjected to incision and cauterisation. Memphis marble as a local analgesic, for example, was finely powdered and applied to the part, and on the addition of vinegar a gas was given off (carbon dioxide) which it is said rendered the part slightly anæsthetic. Various members of the Euphorbiaceæ, Mandragora, and other Solanaceous plants were also employed in infusions, which on being

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drunk induced some narcotism. Sir Benjamin Ward Richardson prepared a draught from some Atropa Mandragora, following the directions given by Dioscorides, and stated that he found the potion a satisfactory anæsthetic. Attempts at anæsthesia by inhalation were very early practised. The Scythians burned cannabis indica and inhaled its fumes to alleviate pain. Snow has pointed out, however, that most of the drugs, the fumes of which were supposed to induce anæsthetic sleep, were really non-volatile, so whatever effect was produced must have arisen from the evaporation of the spirit used in preparing the solutions.

Many cases are recorded in the old writers—to wit, Paris and others—in which the fumes of the dry plant had analgesic effects.

The following passage occurs in Burton's "Arabian Nights," vol. ii. p. 26 : " ' Thy rede is right,' quoth the King, and, seeking his treasury, he took thence a piece of concentrated Bhang; ' if an elephant smelt it he would sleep from year to year.' " Burton writes (footnote, p. 27): " Here the Bhang (almost a generic term applied to hellebore, etc.) may be hyoscyamus or henbane [*sic ?*]. Yet there are varieties of Cannabis, such as the Dakha of South Africa, capable of most violent effect. I found the use of the drug well known to the negroes of the Southern United States and of the Brazil, although few of their owners had ever heard of it."

MANDRAKE.—Gerarde's " Herbal," Norton's ed. 1597, p. 282, writes: " The smell of the apples (mandrake) moveth to sleep." Although mandragora is no longer accepted as possessed of anæsthetic virtue, it is one of the oldest narcotics. Mandragora indeed is said to have been employed freely among the Babylonians 2,000 years B.C., and undoubtedly the Chinese, Egyptians, and Hebrews were familiar with its use.

HELLEBORE.—Woodville's " Medical Botany," vol. ii. p. 275, ed. 1790 : " Hippocrates frequently mentions Hellebore simply, or generically, by which we are told the white is to be understood, as he adds the word ' black ' or ' purging ' when the other species is meant."

In more modern times little advance was made until the nineteenth century. Most surgeons were contented to put their patients deeply under opium. Many " drowsy syrups " were, however, employed in the Middle Ages. The celebrated " Spongia Somnifera " of Hugo of Lucca, a Tuscan physician, and of his son Theodoricus of Lucca (1298), who was a monk, is described

as consisting of opium, hyoscyamus, cannabis indica, mulberry, mandragora, conium, wood ivy, lettuce, and water hemlock. Boccaccio, Shakespeare, and other writers frequently refer to potions given to dull the senses while amputations, and so on, were performed. Such a draught was, it is said, given to Augustus, King of Poland, by his favourite surgeon, Weiss (1782), without the monarch's knowledge, so that the royal foot could be removed without pain. Giambattista Porta, in 1589, recorded his successful use of a mixture—similar to that of Theodoric but in the form of an essence.

In 1661, Greatrakes, a professional " stroker," practised anæsthetic mesmerism. He exploited his art before Charles II. In an MS. dated twenty years later, one Denis Papin wrote that he possessed the means whereby he could abrogate all painful sensations during a surgical operation, but what his method was is left unexplained.

In the sixteenth and seventeenth centuries Valverdi and others operated upon patients stupefied by compression of the carotid arteries, so depriving the brain of blood. In this practice they seem to have been anticipated by the Assyrians, who are reported to have compressed the vessels of the neck to render painless the operation of circumcision. James Moore, an English surgeon, in 1784, revived a suggestion, originally made by Ambroise Paré, that compression of the nerve-trunks should be practised before cutting the areas supplied by them, and John Hunter actually took advantage of the plan, and amputated a leg in St. George's Hospital after firmly compressing the anterior crural and sciatic nerves. Wardrop (1832) proposed to operate upon patients rendered unconscious by bleeding them to syncope. Richerand and other surgeons adopted the plan of rendering their patients intoxicated before applying the knife. Analgesia has been known and practised from remote ages, especially among the Chinese. In 1772 Percival rediscovered the sedative effects of a spray of carbon dioxide, and pointed out that its action necessitated abrasion of the area brought under its influence. The most usual way of obtaining local insensibility was by ice or freezing salt solutions, but Sir John Ross, the Arctic explorer, records the use of a red-hot axe for amputating a leg to obtain hæmostasis and to lessen pain. The use of cold was revived by Larrey, Arnott, Richet, and Benjamin Ward Richardson, who introduced (1866) the ether

spray. In 1845 F. Rynd of Edinburgh invented the hypodermic syringe, and its use was invoked to inject morphine, tincture of opium, and similar drugs into the neighbourhood of nerves. No effective analgesic methods, however, were pursued until 1884, when Koeller introduced the use of cocaine.

A departure in an entirely new direction was made by Mesmer and his followers, who averred that patients thrown into the "magnetic state" (*i.e.* hypnotised) could be surgically treated without any pain or inconvenience. Long before Mesmer lived, a belief had been current that the natural magnet possessed powers which were both curative of disease and capable of establishing anæsthesia. Thus Cardan (1584) recounts how the magnet could be employed to abolish pain. The germs of the facts now known and accepted under the terms "animal magnetism" and "hypnotism" bore a fruitful harvest of windy words, Paracelsus, Glocenius, Burgrave, and others contributing largely thereto. By Anthony Mesmer (born 1734,) however, the matter was advanced from theory to practice, and although we may gird at Mesmer for a charlatan and a quack, we must accord to him a meed of gratitude for establishing upon a practical basis a theory which before his age was lost in useless verbiage. In 1776 Mesmer published his work, "The Influence of the Planets in the Cure of Disease," which maintained that the celestial orbs exercised, by means of "animal magnetism," an all-pervading fluid, an influence benign or malign on human beings. Fourteen years later, in conjunction with a Jesuit, called Father Hell, Mesmer undertook the cure of disease at first by using the magnet and steel "tractors," but finally by means of the manual passes. The plaudits which at first greeted Mesmer in Vienna were ere long changed for the most hostile treatment, the learned bodies of his own and other countries treating his writings with contempt and himself with contumely. Leaving Vienna, Mesmer exploited Paris, and here he founded the widely famed hospital whereat he treated a great number of patients. In 1785 a Royal Commission was appointed to inquire into Mesmer's pretensions, but this and subsequent Commissions unfortunately confused the issues in question, and, while they decided that Mesmer and his immediate adherents were unworthy of credence, they failed to recognise the substratum of truth underlying their teaching and practice. After Mesmer's downfall the subject was kept before the world by the practice of the Marquis de Puységur and the

Somnambulists. In 1829, Cloquet amputated a breast, the patient being rendered insensible through having been thrown into the hypnotic state. Elliotson, a firm believer in the practical uses of animal magnetism in surgery, employed it on several occasions with success. Braid, of Manchester, in 1841 made extensive trial of what he called the "neurhypnotic trance" as a means of producing surgical anæsthesia. Similar experiments were carried out in India by Dr. Esdaile, who performed no less than three hundred operations upon patients in the hypnotic state. Ephemeral attempts have been made from time to time to revive the practice of hypnotism for the induction of anæsthesia with but partial success. It has been found that while only a certain number of persons are capable of being completely hypnotised, even these, as a rule, require many séances under the hands of the "magnetiser" before the requisite degree of insensibility to pain is attained. Again, the mental state thus called into existence is in a large number of cases highly prejudicial to physical and moral well-being, and hence the consensus of opinion at present is rather adverse to the employment of hypnotism in anæsthetic practice, save in very exceptional circumstances and under carefully guarded conditions.* Comparatively recent trials of the effect of exposing to the ultra violet rays of the spectrum an area to be rendered insensitive has not received general acceptance, nor is it made clear whether such a practice is not rather of the nature of a hypnotic suggestion than of a physical effect.

In the eighteenth century the history of discoveries concerning anæsthetic methods becomes merged in that of the progress of chemical research. Hales, Lavoisier, Priestley, and Cavendish opened up rich stores of knowledge by their discoveries in connexion with the gases. Oxygen, nitrogen, nitric oxide, were prepared and closely studied, and, in 1772, Priestley added nitrous oxide gas to the list. Pneumatic chemistry, till then unknown, became the absorbing theme among chemists, while physicians sought to bring the recent discoveries to account by pressing these gases into the service of medicine. Dr. Beddoes in 1798, assisted with finances by Thomas Wedgwood, a son of the

* Prof. Grainger Stewart (*Lancet*, Oct. 21, 1893, p. 1018) wrote: "In every case hypnotic treatment involved hazard to the nervous system, and that those who were most susceptible to its treatment were the most apt to suffer, and that though it might free the patient from one set of symptoms it was apt to make him the victim of many others."

renowned potter, inaugurated his Pneumatic Institution at Clifton, where he proposed to treat phthisis and many other diseases by inhalations of various gases. The gift of Wedgwood's £1,000 was associated with the rather cynical, or perhaps one should say scientific, remark " that it is worth while to expend this sum in order to assure us that elastic fluids would *not* be serviceable as medicines."

The Pneumatic Institute is interesting mainly because its first superintendent was Humphry Davy, who prosecuted therein his researches concerning nitrous oxide and other gases. Southey,* the poet, gives an account of Davy's preparation and trial of nitrous oxide. Davy, Southey, and Coleridge (Coll, as he was called by his intimates) inhaled it. Coleridge attests a highly pleasurable sensation of warmth, or inclination to laugh, and Southey writes to his brother: "Oh Tom! such a gas has Davy discovered!" " Oh Tom! I have had some. It made me laugh and tingle in every toe and finger-tip." "It makes one strong, and so happy! so gloriously happy!" "Oh excellent gas bag! Tom, I am sure the air in heaven must be this wonder-working gas of delight." In 1799 Davy further discovered that "as nitrous oxide, in its extensive operation, appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place." Davy substantiated his statements by most careful experiments upon the lower animals, extending Hales's research, which had been confined to mice, and demonstrating many facts, the practical uses of which were not appreciated until more than forty years later. Davy went a step further, and found the influence of nitrous oxide was sufficient to assuage the pains of toothache. In his researches all his experiments and experiences are carefully set forth; but, except for the tooth incident, we find no suggestion of the use of the gas as a surgical anæsthetic.

Early in the nineteenth century Henry Hill Hickman,† a young surgeon practising at Ludlow, in Shropshire, undertook experiments upon the lower animals with the hope of finding a means of avoiding pain during surgical operations. He investigated

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* See *Life and Correspondence*, vol. ii. p. 21 *et passim*.
† For an interesting account of Hickman see *Brit. Med. Journ.* 1912, vol. i. p. 843. The article is contributed by the Wellcome Historical Medical Exhibition Research.

asphyxia, inhalations of carbonic acid gas and nitrous oxide, and performed operations upon the animals while they were uncon- scious.   His pronouncements were communicated to the medical profession of England and were received with incredulity and ridicule.   An appeal to the French Academy of Medicine met the same fate, and poor Hickman, a veritable pioneer, died, it is said broken-hearted, at the age of 29 (1829).

The discovery of the action of nitrous oxide made by Humphry Davy was not brought within the field of practical application until Horace Wells, a dentist of Hartford, Connecticut, con- ceived the idea of using nitrous oxide gas as an anæsthetic for tooth extraction.   Wells went to a popular lecture delivered before the inhabitants of Hartford by a Mr. Colton, an itinerant lecturer on chemistry.   During the performance one of the au- dience inhaled an impure sample of nitrous oxide and became very excited.   In the course of his gyrations this individual wounded his leg, but appeared to feel no pain, a circumstance of which Wells was not slow to take notice.   The following day, December 11, 1844, Mr. Colton, at the request of Wells, adminis- tered gas to him, and during the ensuing unconsciousness a Mr. Rigg, another dentist, extracted a molar from Wells's jaw.   Wells, as he regained consciousness, cried out, " A new era in tooth- pulling.   It did not hurt me as much as the prick of a pin.   It is the greatest discovery ever made."

After successfully employing gas as an anæsthetic among his own patients, Wells essayed a public demonstration in the operating theatre of the Boston General Hospital.   The person experimented upon was not rendered completely unconscious, and gave unequivocal signs of having felt pain.   This failure not only ruined Wells, who became insane, and finally died in prison by his own hand, having inhaled ether to ensure euthanasia, in 1848, but it also discredited nitrous oxide as an anæsthetic.

With the death of Wells and the introduction of ether as an anæsthetic, the vogue of nitrous oxide, for the time, ceased. Colton, however, remembering his experience at Hartford, revived its use in 1863.   Lee Rymer in England and Hermann in Germany undertook (1864–6) some experiments with nitrous oxide, and the important investigation of Krishaber followed in 1867.

Subsequently Colton induced various dentists to experi- ment, and in 1867 he was able to give a record of 20,000 suc-

cessful cases. In 1868 * the anæsthetic properties of nitrous oxide gas were successfully demonstrated at the Dental Hospital now the Royal Dental Hospital of London, and a committee of the leading English dentists was formed. The two reports published by these gentlemen, and read before the Odontological Society of Great Britain, expressed the warmest praise of the agent, and practically established its claims as a safe and efficient anæsthetic for short operations, in spite of considerable opposition on the part of certain members of the medical profession, who denounced nitrous oxide as unsatisfactory and dangerous.

The enthusiasm and ingenuity of Mr. Clover played no small part in obtaining the adoption of nitrous oxide for general use. It was shortly after this public demonstration of the safety of nitrous oxide that Mr. Clover suggested what may be called one of the most important improvements in practical anæsthetics, the employment of nitrous oxide as a preliminary to the inhalation of ether. †

The discovery of ether is attributed to an Arabian chemist, Djaber Yeber, and its methods of manufacture to Dr. Michael Morris, who also suggested that it could be used with advantage in medicine by inhalation. ‡

The general properties of ether, and its value as an inhalation, were well known before its use was suggested for the purpose of obtaining anæsthesia. In Pereira's work on "Materia Medica and Therapeutics," published in 1839, it is expressly stated that when ether is inhaled to produce a sedative effect in spasmodic diseases, there is a danger that the patient will become stupefied unless the ether vapour is sufficiently diluted. Its introduction as an anæsthetic, however, is commonly held to be due to American enterprise. It was fairly well known, and its properties recognised, as early as 1785, when Dr. Pearson, of Birmingham, employed it as an inhalation for asthma, and early in the nine-

* Colton, while in Paris, met the well-known dentist, the late Dr. Evans, mainly owing to whose energy and munificence Colton's apparatus was conveyed to London, where the merits of nitrous oxide gas were brought before the English faculty.

† See *Trans. Roy. Soc. Med.*, March, 1913, Section of Anæsthetics; and *Lancet*, March 29, 1913. In the latter an interesting leading article appears under the caption of "Joseph Clover, Surgeon and Anæsthetist."

‡ For much valuable information about the discovery of ether and chloroform, the reader is referred to Mr. George Foy's work, "Anæsthetics Ancient and Modern," pp. 23, and 54. The author is indebted to Mr. Foy for various additions made to this chapter.

teenth century it was used in the treatment of phthisis. In 1818 a paragraph appeared in the *Journal of Science and Arts*, which, although unsigned, is generally supposed to have emanated from the pen of Faraday ; it runs : " When the vapour of ether is mixed with common air and inhaled, it produces effects very similar to those occasioned by nitrous oxide." Then follows an account of an experience with ether ; a gentleman who inhaled became " lethargic," and so remained for thirty hours. Facts about the narcotic properties of ether were rapidly brought to light, and the writings of Orfila, Brodie, Giacomini, and Christison all give more or less accurate accounts of the stupefying effects of ether. About the year 1840 it was a common practice at lectures and among medical students to inhale ether-vapour in order to induce exhilaration. About this time a number of lads were indulging in this pastime in the outskirts of Anderson, South Carolina, and, to stimulate further their mirth, they seized upon a negro boy and forced him to inhale ether, pressing the vapour upon him until he became deeply narcotised and apparently dead. In an hour, however, to the delight of his tormentors, the negro resumed consciousness. This scene impressed itself so deeply upon Wilhite, who witnessed it, that when, three years subsequently, he became the pupil of Dr. Crawford W. Long, of Jefferson, Jackson County, U.S.A., he related his experiences to him. Wilhite's claims were carefully examined by Marion Sims, who visited Crawford Long at Athens, and by Landon B. Edwards ; they were convinced that Wilhite was not truthful ; and Landon B. Edwards told Mr. Foy in 1894, at Dr. McGuire's house in Richmond, Va., that Wilhite afterwards confessed his falsehood and said he had concocted the whole story that his name might be associated with the great discovery. Wilhite was not in Crawford Long's employment at the time when the latter etherised his first series of patients.

In 1849 Crawford Long published a statement that seven years previously he had administered ether to a patient, and, while thus narcotised, a small tumour was painlessly removed. Long employed ether successfully in several cases, and the fact was well authenticated by his neighbours and by contemporary documents.* Long, being a busy man as well as of a retiring

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* See *Trans. Roy. Soc. Med.*, vol. v. pt.i. p.19, Section of Anæsthetics, in which a full account of the matter is given by the present writer, and facsimiles of the documents are there inserted.

nature, postponed publishing his cases until he was forced into doing so by the claims of monopoly advanced by Morton. Dr. Crawford Long appears to have acted in all candour, and there can be no doubt that to him is due as a right the title of being the first man who actually employed ether in surgery and proved its value and its safety. Other medical men about this time also employed ether for surgical anæsthesia. It is stated that a student named William Clarke, in 1842, administered ether at Rochester, New York, to a patient for tooth extraction, and Dr. Marcy, also an American, operated upon an etherised patient in 1844.

However, the employment of ether as a general anæsthetic is more usually associated with the name of Morton, a dentist of Boston. William T. G. Morton was a pupil of Horace Wells, and from his master he gathered his first impressions concerning artificial anæsthesia. It would subserve no useful purpose to open up the unfortunate quarrels and recriminations which have been connected with Morton and his share in the introduction of ether as an anæsthetic. It will be best, therefore, merely to state the facts as far as possible without bias.

Wells made Morton his partner in a dental practice he proposed to start in Boston. The removal from Hartford to Boston was consequent upon a discovery Horace Wells had made of some solder with which he hoped to achieve great things. To confirm his own estimate of the value of this solder he called in a Dr. Jackson, a scientific chemist, who expressed a favourable opinion. However, the partners soon fell out, and Wells returned to Hartford, leaving Morton in Boston. The latter asked Wells for information as to the production of nitrous oxide, and was by him referred to Dr. Jackson. It was suggested by the chemist that trial should be made of sulphuric ether instead of laughing-gas, since it was more easily obtained. Morton set to work with great assiduity to experiment, using chloric ether. He induced two students, Spear and Leavitt, to inhale ether, but the results were unsatisfactory. He next tried dogs, and using rectified ether, again at Jackson's instance, himself inhaled it from a tube attached to a flask. This is the story of Morton's discovery, given in his own words: " I procured the ether from Burnett's, and, taking the tube and flask, shut myself up in my room, seated in the operating chair and inhaling. I found the ether so strong that it partially suffocated me, but

produced a decided effect. I then saturated my handkerchief, and inhaled from that. I looked at my watch, and soon lost consciousness. As I recovered I felt a numbness in my limbs, with a sensation like nightmare, and would have given the world for some one to come and arouse me. I thought for a moment I should die in that state, and that the world would only pity or ridicule my folly. At length I felt a slight tingling of the blood in the end of my third finger, and made an effort to touch it with my thumb, but without success. At a second effort I touched it, but there seemed to be no sensation. I gradually raised my arm and pinched my thigh, but I could see that sensation was imperfect. I attempted to rise from my chair, but fell back. Gradually I regained power over my limbs and full consciousness. I immediately looked at my watch, and found that I had been insensible for between seven and eight minutes." A patient, Eben Frost, seeking to have a tooth taken out, and fearing the pain, requested Morton to mesmerise him, mesmerism being at this time in vogue in such cases. Morton promptly seized his chance, and persuaded Eben Frost that he knew a far better means of preventing the pain. The experiment was made, and on September 30, 1846, ether was successfully given by Morton and a tooth painlessly removed. The " discovery " was reported to Warren, the well-known surgeon, and by his consent a patient was etherised in the clinical room of the Massachusetts General Hospital.* The experiment was repeated, and each time proved a remarkable success. Warren, however, substituted chloric for sulphuric ether in subsequent operations, and is said to have preferred it.†

The possibility of producing anæsthesia by inhaling vapours having become an accomplished fact, it became necessary to find words expressing the agents used and the state induced. Morton adopted the term " Letheon,"‡ but this word soon fell into de-

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* The date of Dr. Warren's operation in which Morton first etherised a patient in the Massachusetts Hospital, Boston, as given by H. J. Bigelow in the *Boston Medical and Surgical Journal* of November 18, 1846, is October 16, 1846.

† " Personal Recollections of the First Use of Anæsthetics," by J. V. Galloupe, M.D.. *Boston Medical and Surgical Gazette,* January 7, 1897.

‡ " Letheon " was the fancy name given for the drug which Jackson and Morton patented ; hence was avoided by medical practitioners, probably because the smell of the anæsthetic revealed its identity with ether. Dr. King, of Boston, was one of the first to attack the validity

suetude after the suggestion by Oliver Wendell Holmes of the expressions Anæsthesia for the state, and Anæsthetic Agent for the drug employed. Simpson regretted that the word Nodynia had not been accepted rather than Anæsthesia.

In England, the first administration of ether took place in Gower Street, London, close to University College Hospital, when Mr. Robinson, a dentist, gave ether and removed some teeth. This took place on Saturday, December 19, 1846, at the house of Dr. Boott. On Monday, December 21, Liston amputated through the thigh in University College Hospital, the patient being placed under the influence of ether by Mr. Squire. The patient was made to inhale through a tube connected with a flask, or Wolff's bottle, in which were pieces of sponge saturated with ether.* It is probable that Joseph Lister (afterwards Lord Lister) and Joseph Clover, who were at this time students at University College, were present on this occasion.

Dr. Snow, early in 1847, commenced the successful administration of ether in St. George's Hospital, but upon the introduction of chloroform he gave up ether for its more pleasant but possibly less safe rival.

On January 19, 1847, Dr. (afterwards Sir) James Young Simpson administered ether to a woman in childbirth, and subsequently adopted it in his obstetric practice. Notwithstanding the favourable experiences of many, ether was not rendered popular for some years subsequently. The methods in vogue for its administration were far from satisfactory; many patients never got beyond the stage of exhilaration and wild excitement, and their struggles and bacchanalian shouts were pronounced highly embarrassing to the operator. These considerations led Liston and other eminent surgeons to regard ether with suspicion, and made them diffident in invoking its aid. However, up to November 1847, the time of Simpson's world-famous pamphlet, " Notice of a New Anæsthetic Agent as a Substitute for Sulphuric Ether in Surgery and Midwifery," ether was slowly but surely winning its way as a safe and trusty

of the patent, and in Great Britain and Ireland the most trenchant critic of the action of the " Letheon " patentees was Dr. Arthur Jacob, *Medical Press*, 1846.

* An extremely interesting and graphic account of this episode has been written by Dr. F. Cock, and published in the *Univ. Coll. Hosp. Gazette*, February, 1911.

anæsthetic. With the introduction of chloroform came the *coup de grâce* to the predominance of ether. With an almost incredible rapidity chloroform supplanted her elder sister, not only in Great Britain but almost throughout the world; in America, however, most surgeons still clung to ether. The story of the introduction of chloroform into Great Britain is soon told. Sir James Y. Simpson,* not wholly satisfied with ether in obstetric practice, asked Mr. Waldie, the Master of the Apothecaries' Hall of Liverpool, if he, as a practical pharmacist, knew a substance likely to be of service in producing anæsthesia. Mr. Waldie, being acquainted with the composition of "chloric ether," suggested that its "active principle," chloroform, should be prepared from it and used. He never carried out his promise to prepare some for Simpson to try, and so the desired substance was obtained in Edinburgh, and Simpson, experimenting on himself, on George Keith, and Matthews Duncan, on November 4, found its use perfectly satisfactory. He at once tried chloroform in his obstetric practice and met with success.

The favourable opinion he had formed he expressed in his paper before the Medico-Chirurgical Society of Edinburgh, November 10, 1847. On November 15, 1847, the first surgical operation was performed in Edinburgh, upon a patient who was under the influence of chloroform. It is curious to note how near several persons came to the discovery of the value of chloroform as an anæsthetic. Thus, chloric ether, a twelve per cent. solution of chloroform (by volume) in spirits of wine, was employed by Dr. Bigelow, of Boston, but with only partial success. Jacob Bell, of London, however, actually produced insensibility by its use given as an inhalation, and Sir William Lawrence, the surgeon, employed it alike in private and hospital practice. Chloric ether was used both at St. Bartholomew's and the Middlesex Hospitals, but the great uncertainty of its action and the expense of procuring large supplies effectually prevented its acceptance as an anæsthetic.

Mr. George Foy has pointed out that in Silliman's *American Journal of Science and Art*, January 1832, Professor Ives, of Newhaven, U.S.A., reports a case in which chloroform was employed as an anæsthetic. Guthrie, an American chemist, was induced

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* For an account of Simpson's work in connexion with the introduction of chloroform, see "Sir James Y. Simpson" in Famous Scots Series. Also see Simpson's "Collected Works," vol. ii., "Anæsthesia."

by a statement in Silliman's "Chemistry" that an alcoholic solution of chloric ether was a valuable stimulant, to attempt a cheap way of producing it.* Guthrie gives directions for the distillation of chloride of lime and "well-flavoured alcohol" of sp. gr. 0.844. Soubeiran's account of his discovery of chloroform, made apparently without any knowledge of Guthrie's work, appeared six months after Guthrie's MS. was in the printers' hands. About the same time another independent observer, Liebig, published an account of chloroform, but in his analysis he failed to recognise the presence of hydrogen, and regarded the material as a chloride of carbon. It was not until 1834 that Dumas, adopting more exact methods, revealed the true chemical composition. Chloroform was experimentally studied by Flourens in 1847, but no practical uses were then made of his work.

For some while chloroform was believed to be a "safe anæsthetic," an impression to which the language of Simpson's pamphlet rather lent itself, although certainly no explicit statement to that effect can be found. Unhappily this belief received a rude shock on January 28, 1848, when a death from chloroform was reported at a place near Newcastle-on-Tyne. This untoward occurrence was soon followed by other deaths, and men's minds became anxious. At this pass Snow, with that earnestness and acumen which characterised all he undertook, commenced his researches upon the subject. In 1848 he published his "Experimental Papers on Narcotic Vapours." Ten years later he published an account of an apparatus by which chloroform vapour could be given more or less dosimetrically. Although his inhaler permitted a nominal maximal percentage of vapour equal to 4 volumes in 100 volumes to be evaporated from the bibulous paper on which the chloroform was immersed, yet valves in face-piece permitted greater dilution of the vapour before it reached the patient. Snow recognised and taught that the optimum value for safety was 2% and this was reaffirmed by Paul Bert after experiments published in 1884, and Dubois also accepted this maximum and graded his chloroform machine upon such a basis.

Although Snow had improved upon the methods in vogue for the exhibition of ether by the invention of his inhaler, he

* See "The True History of the Discovery of Chloroform," by David Waldie, Edinburgh, Oliver and Boyd, 1870.

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did not vaunt its merits above other narcotics, and in 1847 he perfected his chloroform inhaler, being actuated by the belief that that anæsthetic kills through being used in too concentrated a vapour. Snow's experience, like that of most others, made him regard chloroform as dangerous, and so in 1856 he was tempted to investigate amylene, of which substance he entertained a high opinion.

A committee appointed by the Royal Medico-Chirurgical Society of Great Britain to investigate the subject of anæsthesia tendered their report in 1864, and this report strongly insisted both upon the danger of chloroform and the inconvenience of ether as then administered. Dr. George Harley contended that in mixtures of chloroform and ether the latter counteracted the circulatory depression incident to chloroform. He therefore devised the A.C.E. and the C.E. mixtures, and these were largely adopted, although, as we now know, they were based upon the above assumption, the fallacy of which was demonstrated many years later by Sir Edward Sharpey Schäfer. It is interesting to note that no anæsthetist sat upon this committee, although Mr. Clover was asked to act as an adviser and tendered his valuable advice. Dr. Harley was, of course, a distinguished physician. Many suggestions were embodied in the report, some of which Clover, who had then achieved a high reputation as an anæsthetist, was not slow in carrying to a practical issue. In 1862 Clover had constructed and published an account of his chloroform apparatus by which he regulated the percentage of vapour administered.

Pollock and Warrington Haward in this country were keenly alive to the dangers of chloroform, and they lost no opportunity of urging the use of ether, an advocacy for which we must always feel grateful. As time went on, Clover was less and less inclined to use chloroform. For minor operations he found nitrous oxide gas given by his apparatus to answer best, and he was led to seek some means for prolonging anæsthesia so obtained. This he achieved by the employment of ether in succession to nitrous oxide, for which he soon devised an admirable apparatus, described in the *British Medical Journal* in 1876. It may be remarked that this inhaler is at the present time less known than its merits deserve. Subsequently his portable regulating ether inhaler was introduced, and it was mainly by the compactness and efficiency of this instrument that the practical question, how to

give ether rapidly and safely, became answered. Clover pointed
out that it was essential that all bores in the apparatus should
at least equal the calibre of the trachea; but that, as the patient
obtained his supply of air and vapour from the " dead space " en-
closed in the face-piece, no excess in the diameter of the bore was
essential, or indeed desirable, as it increased the " dead space "
and so rendered inspiration more laborious. A perusal of
Mr. Clover's papers reveals a meritorious and meticulous care
and attention to detail worthy of all praise. In latter years he
adopted the use of " dichloride of ethidene," first introduced
under the name of " monochlorurretted chloride of ethyle "
by Snow in 1851, but the record of 1,877 cases with one death
did not lead to the general adoption of this anæsthetic.

In 1879 the British Medical Association undertook to rein-
vestigate the question of the relative safety of the various an-
æsthetics, and appointed a committee to carry out experiments.
The conclusions to which this, the " Glasgow Committee," arrived
were in favour of ether, as they found chloroform lowered the
blood pressure and depressed the action of the heart. No record
dealing with the earlier work done concerning anæsthetics would
be complete without a reference to the valuable researches of the
late Sir Benjamin Ward Richardson, the biographer of Snow.
Many of his papers appeared in his journal, *The Asclepiad*, and
other periodicals. " Bichloride of methylene," * a proprietary
preparation at one time widely used, was one of Sir B. W.
Richardson's contributions to general anæsthesia, as ether spray
was one to local analgesia. In 1889 the Nizam of Hyderabad,
at the suggestion of the late Surgeon Lieut.-Colonel Lawrie,
granted a considerable sum of money to reopen the question,
and the first Hyderabad Commission, working upon small
mammals in India, came to conclusions more favourable to chloro-
form. As these investigations were not held convincing by
English experts, a second Hyderabad Commission, in which the
late Sir Thomas (then Dr.) Lauder Brunton assisted, went over
the ground again, and reinvestigated the earlier experiments
and reaffirmed some of the results before obtained by the first
Hyderabad Commission. The *Lancet*, with public-spirited zeal,
undertook and carried out an exhaustive report dealing with
the clinical evidence on the uses of chloroform and other an-

* Analysis has revealed the fact that the fluid called " methylene " is
in fact a mixture of chloroform and alcohol, and it has fallen into desuetude.

æsthetics, and published it in 1893.* The results of clinical observations therein embodied did not bear out all the statements of the Hyderabad Commission.

The British Medical Association, as a result of a discussion held at the Annual General Meeting at Bournemouth in 1891, when the present writer, at the request of the local secretary, Dr. C. Childs, read a paper on " The Clinical Aspects of Anæsthesia," † appointed a committee to study the question. The object of the paper then read was to point out that, although there were many cases published of deaths under chloroform, yet no statistics existed showing the number of normal cases in which chloroform was used, so that it was a matter of guesswork to estimate a percentage rate of safety for that and other anæsthetics. The paper further demonstrated that careful records of cases which, although not terminating fatally, yet presented slight or grave dangers, must prove of value by elucidating how such dangers were caused and how they could be obviated. The report of this committee appeared in 1900, and contained an analysis of 25,920 cases in which anæsthetics had been given and records kept. Lord Lister contributed articles to Holmes' System of Surgery dealing with the chloroform question, and these have been reproduced in the collected works. Lister's attitude was one of unswerving faith in chloroform when given by an open method. Of dosimetric methods he had no experience, while the quasi-open method enforced in Syme's clinic was familiar to him. He contested Paul Bert's statements, and carried out various experiments upon mice, and upon himself. These reveal the astuteness of mind which featured all his work, but failed through lack of satisfactory " controls " being instituted. Still, Lister's name must be inscribed among those of the early and most esteemed workers on anæsthetics.

The important researches of Gaskell, Hare, Leonard Hill, Levy, McWilliam, Shore, A. D. Waller, and Wood, have all appeared within the last few years, and have kept alive the controversy which has existed since the initial use of chloroform. These experimental results are considered more at length in the chapter dealing with chloroform.

* This report was undertaken by the present writer, his work being facilitated by the encouragement given by the proprietors of the *Lancet*, and especially by that of the late Mr. Thomas Wakley, jun.

† *British Medical Journal*, vol ii. p. 1090, 1891.

It is not within the scope of this book to notice in detail the more recent work which has been sufficiently constructive to deserve a mention in the history of the subject. It may, however, be noted that Dr. Embley, of Melbourne, working with Dr. Martin, by an important research, has increased our knowledge of the obscure subject of vagal inhibition during narcosis. This and other researches appear in the *Transactions of the Society of Anæsthetists*, a society which has done much to promote an intelligent study of anæsthetics. It now forms a section of the Royal Society of Medicine. The British Medical Association (1901) again testified its public-spirited interest by appointing a further committee * to investigate methods of quantitatively determining the presence of chloroform in the air and in the human body. The work of this committee has been published in an accessible form, the volume containing both the original papers and illustrations and the final report of the committee.

Perhaps the most remarkable advance made in anæsthetics during the last few years is the adoption of methods of introducing ether and other drugs directly into the blood-stream, and the intratracheal insufflation of ether directly into the lungs. In this connexion must be mentioned the work done by Professor Meltzer of the Rockefeller Institute. It is owing to his experiments that the intratracheal method of exhibiting anæsthetic vapours has become possible. By this, as by much other most valuable experimental work, Professor Meltzer has advanced our knowledge of medicine and surgery.

* The committee, as first appointed, consisted of Dr. (now Sir James) Barr, Dr. Dudley Buxton (Secretary), the late Mr. Vernon Harcourt, F.R.S., the late Sir Victor Horsley, F.R.S., Professor Sherrington, F.R.S., and Dr. A. D. Waller, F.R.S.

CHAPTER II.

PREPARATIONS FOR OPERATION : SELECTION OF THE ANÆSTHETIC AND METHOD.

GENERAL PRELIMINARIES.

Best time for taking an anæsthetic.—Although the anæsthetist but seldom has the choice of time left to his judgment, the selection of a suitable hour for the operation is not a matter of indifference in administering an anæsthetic. The effect of anæsthetisation upon the robust may be considered trifling and transient, but when the person to be anæsthetised is an invalid, and either weakly or neurasthenic, the inhalation may have a dangerous and prolonged effect. Individuals are more liable to serious after-effects when their bodily condition is one of nervous exhaustion and lowered vitality. It is inadvisable, therefore, unless over-riding circumstances exist, to give an anæsthetic after an unduly prolonged fast. Similarly, it is unwise to select an advanced hour of the evening when the body will be spent after a day of activity or suffering. In the case of emergency operations, delay may be prejudicial, so that the above statements must be accepted as being applicable only to " arranged " operations.

Dietary.—An anæsthetic should not be given within three hours of a meal of such food as is not easily digested, since a full stomach is liable to impede the production of narcosis and to excite vomiting. This last, if occurring during light narcosis, may occasion fatal accidents through solids being drawn into the air-passages. It is well to select the periods of greatest vital activity, and this is found in most persons in the morning (8 a.m.) or early afternoon (2 p.m.). Speaking generally, it is well to arrange for a very slight meal of soft and easily digested matters to be taken three, or better four, hours at least before the surgeon arrives. But it is best, when possible, unless the patient be in a very feeble state of health, to adopt Clover's rule, and give the last meal

five or six hours before the operation. In the case of robust adults when the operation is to take place in the early morning, no food need be taken after the overnight dinner. This meal should consist of either broth, soup freed from fat, meat jellies, or easily digested foods, varying with the time of the day, and the choice of the patient. Milk, if taken by itself, is very apt to form curd, which will be vomited in hard masses during the operation. This is especially the case with young children. Barley water added to the milk will often obviate the clotting. A pinch of citrate of soda added to the contents of the feeding-bottle (3 parts milk and 2 parts barley water) will prevent stomach upset in infants. It is not wise to make the administration of stimulants before an anæsthetic a matter of routine. In every instance it is recommended that the bowels be cleared overnight with a laxative, and followed in the morning by an enema. A still better plan is, when the patient is under control for some days before the operation, for the bowels to be cleared out by medicine given on the second night *before* the anæsthetic is administered, followed by an enema on the morning of the operation. But some surgeons prefer, in the case of abdominal sections, to dispense with purgatives, and give copious enemata daily for a week before operation. Patients are spared much discomfort if they are dieted for a day or two before the operation. Only light, nutritious foods should be given. The bowels must be carefully regulated. It often happens that a strong purgative, given the night before an anæsthetic is administered, upsets the digestion, and in bilious subjects increases the after-sickness. It is also as well to avoid, as far as possible, interference with the usual hours of the patient's meals, as food taken when the stomach is not accustomed to it is liable to remain undigested and to cause vomiting. This is still more important in the case of the weakly and of those enfeebled by disease. A prolonged fast, or too free purgation, is very liable to produce syncope or other dangerous symptoms at the time of the operation. In feeble subjects a nutrient enema of some reliable meat extract or a nutrient suppository may be given half an hour previous to the operation. In all cases of great exhaustion or collapse before operation and when there is obviously poor resistive power, enemata containing glucose (ζ j) in saline (ζ vi) should be given at four hours' interval for 48 hours before and after the anæsthetisation. In cases of abdominal sections some surgeons recommend copious

draughts of hot water when these are not contra-indicated, given every four hours for three or four days before the operation to prevent sickness and thirst. This mode of stimulation is in all cases a better plan than that of giving alcohol by the mouth. The restriction of feeding should be less severe in the case of children, since they become rapidly exhausted if made to go without food for more than three hours. For them glucose and water, or even ordinary sugar, is useful, and may be given two hours before the inhalation, but the bulk of fluid allowed should be small. Babies may take the breast or the bottle one or one and a half hours before the operation. If bottle-fed, Sodii Citr., lime water or barley water should be added to the milk.

The following is a condensed form of a usual regimen to be adopted at the time of an operation other than in abdominal cases :—

Operation at 9 a.m.

No food unless the patient is greatly depressed ; if he is, a small cup of China tea with toast or Plasmon biscuit soaked in it, at 6 a.m. ; or a small basin of thin cornflour, or a tumbler of hot water containing glucose.

After the operation at 9 a.m., completed by 10 : if sickness occur, very hot water in which sodii bicarb. (3j to Oj) is dissolved may be given in sips from a feeder or porcelain spoon. As a rule, if actual vomiting has occurred a small glassful of this alkaline drink gives the greatest relief and stops the sickness. At 2 p.m. essence of beef in jelly ; if much thirst, hot water with a little citrate of soda may be freely given, or ice may be sucked, or iced soda and milk taken.

If very prostrate from vomiting, iced champagne or brandy and soda water may assist recovery, but hot coffee without milk is probably better.

At 6 p.m. a light meal of fish, unless the vomiting has persisted.

Operation at 2 p.m.

Breakfast at 7, tea or thin cocoa, bread boiled to a pulp in milk, fish, but no meat.

Clear soup or good beeftea in small quantity (free from fat) if desired, at 11 a.m.

After the operation at 2, over at 3 : Bread and milk, or biscuit and tea or cocoa, at 7 p.m.

When nutrient enemata have been given for some days pre-ceding the operation it is well to let the patient sip hot water to allay the thirst, which otherwise may prove almost intolerable. Although beeftea is recommended, it is essential that it should be made at home and with great care. There must be no excess of salts. Some of the meat extracts are specially adapted for invalids, and answer the purpose of beeftea. The whole question of feeding before taking an anæsthetic is a complex one, and is only to be answered after an accurate knowledge of the patient's digestive powers has been obtained. A dilated stomach contra-indicates liquid food taken by the mouth. Much incon-venience is prevented when rectal alimentation can be practised, but it should be pursued for some days in order to test its efficacy. Lavage is often valuable, but in many cases it produces exhaustion, even collapse, and so its effects must be carefully watched. The best results are certainly obtained when the usual habits as regards the hours of meals and the quantity of food taken are followed so far as is possible. Naturally the nature and severity of the operation must influence the anæsthetist in prescribing a pre-anæsthetic regimen.

If only **nitrous oxide** is given, strict preparation may be omitted. Even in this case it is well that an interval of some hours, pre-ferably three or four, should intervene between the last meal and the administration. Fasting for several hours is best for patients who have to take nitrous oxide with oxygen, or ethyl chloride, even when for dental operations, as nausea and vomiting are not infrequent after these anæsthetics. In the case of children especially, it is well to see that they pass water before being anæsthetised, as micturition is often performed unconsciously whilst under the influence of nitrous oxide gas.

Preparations for anæsthetic.— Assuming that the physical condition, as far as is necessary, has been examined (see p. 28), the patient about to be anæsthetised should be placed in the recumbent position, except in the case of dental operations under nitrous oxide. The clothing should be either replaced by warm night-wear or, in minor operations, carefully loosened, corsets quite undone, neck-bands left open, waist-belts removed and strings untied. It is important that the patient be as com-fortably posed as circumstances will permit, for while tranquillity of mind and body go far to assist in the production of anæsthesia, anxiety and uneasiness will greatly retard its accomplishment.

The patient should now be asked to open his mouth, and a glance given to ascertain if any artificial dentures or an obturator, etc., be worn. Such, if present, must be removed with as little annoyance to the patient as possible. It is wise to notice whether any loose teeth are in the mouth, as, if it has to be opened with a gag, the teeth may be disengaged and enter the air-passages. Any obvious obstruction such as a goitre, enlarged tongue, or if the tongue is bound down by adhesions, enlarged tonsils, hypertrophied uvula, nasal polypi, etc., should be looked for. A further step may be taken in reassuring the patient by a few cheery words, and, if necessary, directions as to how he is to take the anæsthetic. Such instructions are often of marked service by giving him something about which to think.

When, however, the anæsthetic is once well on the way, quietness and silence must be maintained; noise—notably in the case of nitrous oxide—militates considerably against easy and tranquil anæsthetisation.

Avoid conversation, especially about cases of patients who have died or suffered mishaps. A person going under an anæsthetic is apt to obtain a confused notion that the remarks apply to him, and he will grow nervous and excited. Similarly, during the recovery, a patient often appreciates what is being said by those standing about him when they imagine he is still unconscious.

Some conditions require special preparation of the patient. In operations for strangulated hernia, intestinal obstruction, and other cases, when there has been persistent vomiting, it is best, if the patient's state permits of it, that his stomach should be thoroughly cleansed, its contents being withdrawn by lavage and washing out with warm water. This precaution helps to obviate the fatal aspiration of vomit into the air-passage during anæsthesia.

It is also well, when the patient is weakly, to wrap him warmly in flannel or cotton-wool, as a prolonged operation under an anæsthetic usually occasions a considerable fall of temperature and renders the patient more liable to shock, bronchitis, and pneumonia.*

The room in which an anæsthetic is given should be well ventilated, but ought to be kept at a temperature of 65° or

* The advantage of using warmed anæsthetic vapour is considered in the section dealing with ether.

70° F. It is undesirable to have gas burning in it, as, when
chloroform is being used, that anæsthetic becomes decomposed,
acrid fumes of phosgene gas are generated, and these are not
only very irritating to the eyes and throat, but deleterious to
the patient and to all in the room. It is always best that pre-
parations for the operation be made out of sight and hearing
of the patient. It may not be out of place here to insist upon
the extreme importance on the part of the anæsthetist as regards
cleanliness. All **apparatus** should be carefully cleansed before
use, and the anæsthetist's **hands** and **nails** rendered absolutely
clean. Not only is it unpleasant for the patient to see a dis-
coloured hand near his face, but frequently the hands and
apparatus of the anæsthetist cannot be kept out of contact with
the area of operation and may be a source of **infection**.

Moving an anæsthetised patient.—It is never desirable to
administer an anæsthetic to a patient on his bed, and subsequently
carry him into the room in which the operation is to be performed.
It is apt to cause vomiting. I have more than once seen alarming
faintness occasioned by lifting the patient on to the operation-
table after he was carried from one room to the other. If,
however, on account of the patient's extreme nervousness, or
for other reasons, it is deemed best to anæsthetise him in an
anteroom, the utmost care must be taken in carrying him into
the operation-room, unless there is a properly made webbed carrier
with poles. Adults may be carried by four persons, each taking
a corner of the sheet or blanket on which the patient is lying.
When possible, the removal should be done by means of a trolley
running on rubber tyres. If the patient is conveyed from
one floor to another, his head should be kept lower than his body,
provided this position is not inconsistent with the necessities
of the patient or the nature of the operation. The same care
should be taken in replacing him in bed after the completion of
the operation. No patient should be left alone until he has
fully regained consciousness, as the state of returning volition
has special perils. The dangers to be looked for and guarded
against are: (1) the head may roll into a faulty position and
respiration become impeded; (2) the patient may become
asphyxiated by aspirating vomitus when his head is not turned
to the side; (3) the patient may suddenly sit up, as in the act
of vomiting, and faint.

Vomit is often very irritating, especially if bilious. I know

of cases in which the fluid was allowed to go into the eye, causing conjunctivitis and pain for some hours subsequently. Possibly the vapour of the anæsthetic which is condensed in the mouth and swallowed may account for the deleterious character of the vomit. To obviate this risk, as well as to safeguard against the irritation caused by the anæsthetic vapour during inhalation, a few drops of pure castor-oil may be dropped into the eyes as soon as the patient is unconscious and a pad of lint then placed over them.*

When alkaloids are to be employed the injection should be made one hour or one hour and a half before the anæsthetic is given. After this the patient must be kept absolutely quiet, and no talking or movement should be allowed in his room, nor must he be allowed to walk to the operating-room, as such a proceeding will certainly occasion giddiness or even faintness.

The choice † **of an anæsthetic** must depend upon

    1. The condition of the patient.

    2. The necessities of the operation.

1. CONDITION OF PATIENT.

The choice of an anæsthetic in any case can only be satisfactorily made after a careful examination of the patient, and the nature and probable severity of the operation to be performed have been ascertained. Besides the actual malady for which operation is proposed, it must be ascertained whether intercurrent pathological conditions are present.

Examination of the patient.—The physician who is in charge of the patient can usually give us all requisite information about his general condition, but it is desirable that the anæsthetist should have the opportunity of making a personal examination. ‡ When possible this should be done the day before the operation, as it is better not to expose or fuss the patient just before he submits to the anæsthetic. The examination should be conducted as quietly and reassuringly as possible.

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* Some castor-oil is said to contain croton-oil, which is a powerful irritant.

† The question with whom lies the choice of the anæsthetic is considered in detail in Chapter XII.

‡ See discussion on the desirability of the anæsthetist examining the patient, *British Medical Journal*, 1912, vol. ii. p. 612. A strong consensus of opinion favoured the view given above.

GENERAL APPEARANCE: POSTURE.

Much can be learnt by inspection. The colour of the skin, whether the lips and ears are bluish or anæmic, pitting of the skin, pallor or plethoric redness, are all important signs. Alertness, sluggishness, or feebleness in movement betokens vigour or the reverse. The posture naturally assumed must be noticed, as, if it indicates the presence of dyspnœa or orthopnœa, it is also the position which is most favourable for the patient when under the anæsthetic. This is of great importance in cases of goitre and other neck swellings, of thoracic disease, empyema, and kindred troubles—also in cases of abdominal distension, especially when the patient is obese—and the utmost care should be taken to retain the patient in this posture so far as the exigencies of the operation permit. If a change-of position has to be made it must be done slowly, and the effect of it carefully noted. At the close of an operation undue and rough lifting of the head and trunk often causes faintness and promotes vomiting, as is frequently noticed after severe operations on the breast. The eyes should be looked at, and dilatation or contraction of the pupils as well as the ocular movements noticed. It should be ascertained whether belladonna, opium, homatropine, or other drugs have been taken or recently applied. The presence of habits of excessive indulgence in alcohol or tobacco may with advantage be investigated, as the former tends to produce excitement and delay during the induction of anæsthesia, and the latter not infrequently induces pharyngeal catarrh and intolerance towards ether.

A fixed, rigid chest, with straight shoulders, as a rule, means a dangerous and difficult narcosis, even if no active disease is present. The plethoric and short-necked, and the unduly fat with protruding abdomen, are always short-winded and subject to respiratory difficulties under the anæsthetic, being very prone to spasm affecting the respiratory tract. I am sure that too doctrinaire an adhesion to the rule that the head and neck must be kept low during induction is a mistake in these, and indeed in many other cases. Provided the head is not flexed on the trunk, short-necked and stout persons breathe best when their head and shoulders are on an inclined plane and higher than their abdomen. After induction they can, if necessary, be lowered, and certainly should be so placed if the opera-

tion is upon the abdomen or involves much hæmorrhage. This matter is referred to in a later chapter.

Too much importance should not be attached to the pulse rate. It may run up to 100 or more in nervous people. Of course, a pulse rate above 100 associated with proptosis suggests the serious condition of true tachycardia and calls for most careful examination, and for corroborative evidence of disease. The regularity in force and rhythm and compressibility are of greater moment, and will give a clue to the condition of the circulation and to the patient's resistive power against shock. Intermittence of the pulse is often congenital and unimportant, and can, if present, usually be explained by the family doctor. In every case the urine, both as regards quantity and the presence of pathological constituents must be examined. If the chest and abdomen can be studied, the main points to be observed are briefly : the general conformation of the chest and the movements of the two sides ; the presence of abnormal pulsation and the area of cardiac impulse and dulness ; the characters of breath and heart sounds, and, if murmurs exist, their character—whether hæmic or not—and the direction of their conduction. The evidence of valvular disease is of less importance than whether the lesion revealed is compensated or not. If the impulse is feeble and the heart sounds distant, it is well to ascertain, as far as can be done, whether there are further signs of a fatty and feeble heart muscle. Such a condition is of very much greater import than mere intracardiac valvular disease unassociated with consequent pathological changes.

Displacement of the heart from whatever cause should be most carefully noted, both, because the condition may arise from intrathoracic causes which are probably detrimental to the respiratory or circulatory functions, or from pressure from the abdomen, a condition possessing its own dangers in the direction of inducing syncope, and because it may evidence cardiac dilatation and hypertrophy with probable disabilities. In all cases of obvious frailness or feebleness the height of blood-pressure should be carefully noted, and further and useful help should be obtained by the use of Dr. Oliver's arteriometer.*

* See " Studies in Blood Pressure, Physiological and Clinical," 3rd edition, by Dr. G. Oliver, edited by Professor Halliburton for further information upon this point ; also " Observations on Blood Pressure," by Dr. Rudolph, Canadian Institute *Transactions*, vol. vii.

The value of noting blood pressure was advanced by the author in cases of shock, and wider experience has convinced him of it.* It is also wise in cases of grave anxiety to examine the blood, making not only a blood-count, but an estimation of the hæmoglobin. Inspection of the neck must also be carefully made to determine whether there is any swelling or undue shortness and fulness, and if the veins are normal, dilated, or incompetent. Goitre, enlarged glands, and inflamed areas in this region will often cause respiratory difficulty, and, unless a judicious choice of the anæsthetic be made, will probably lead to disaster.

The general inspection having been made, we may consider the condition of the patient more in detail.

The upper air passages and thorax should be examined for any cause of **dyspnœa.** This may arise from *nasal obstruction, morbid growths* blocking the nasopharynx, *vegetations, polypi,* etc. ; from *hypertrophied tonsils* or *uvula* ; *morbid growths* or *œdema* of the *palate, fauces, tongue, gums,* or *posterior pharyngeal wall* (*e.g.* spinal abscess) or *larynx.* In stenosis narium, more especially when associated with valve-like insucking of the muscular lips of the edentulous, inspiration becomes greatly hampered. Inflammatory conditions, *e.g.* angina ludovici or goitrous growths. and other swellings, whether glandular or not, are liable to interfere with breathing, the dyspnœa as a rule increasing as the patient passes under the anæsthetic. When postnasal adenoid growths and hypertrophied tonsils are found associated with enlarged cervical glands the possibility of the condition called lymphatism must be borne in mind. Search should then be made for general glandular enlargement, the presence of an enlarged thyroid gland, and a persistent thymus. It is stated that this last can sometimes be detected either by percussion or by its casting a shadow upon the screen under X-rays. The other symptoms need not be adverted to in this place.† Epistaxis may prove a troublesome complication and any tendency to it should be borne in mind.‡

* See *Trans. Roy. Soc. Med.,* 1909, vol ii. pt. i. p. 55.

† See *Trans. Soc. of Anæsthetists,* vol. iii. p. 41, in which Dr. McCardie discusses lymphatism ; and a clinical lecture by the author in the *Lancet* August 6, 1910, in which is reviewed the present knowledge of this curious condition.

‡ The possibility of foreign bodies passing from the alimentary tract into the upper air passages should be remembered. Besides regurgitation of fluids, etc., from the stomach, I have met with a case in which round worms were passed up in this way and caused respiratory obstruction.

Tumours in the neck or thorax may, by pressure upon the trachea or bronchi, cause dyspnœa, *e.g.* aneurism, lymphadenoma. Laryngeal œdema, obstruction, or paresis should be looked for.

Diseased conditions of the *nervous system* may cause interference with respiration through pressure upon the spinal cord or pons, and upon the roots of the nerves associated in the act of breathing. Thus I have on several occasions given chloroform to patients whose respiration was solely diaphragmatic, or greatly affected through injury to, or disease of, the spinal cord, or by cerebellar or bulbar tumours. Conditions such as these should induce the anæsthetist to minimise the quantity of chloroform given, as ordinary doses would prove fatal.

Pulmonary and *pleural diseases* are referred to more in detail below. Dyspnœa, accompanied or not by fever, cough, expectoration, hæmorrhage, fixation of the chest, or unequal and impaired movements, indicate the avoidance of any anæsthetic or method of giving it which might increase the respiratory embarrassment. Ether, if forced and associated with increased secretion of the mucous and other glands or with cyanosis, would, for example, almost asphyxiate in such conditions; but chloroform slowly given in a high dilution would be well borne, and may in suitable cases be followed by ether.

The colour of the patient is a material point in these conditions, as well as when the heart is working at a disadvantage. *Cyanosis,* from whatever cause, increases the risk of the anæsthetic, and every means should be adopted to obviate it. I have found oxygen serves most usefully as an adjunct both to ether and to chloroform in dealing with such conditions, and in cases of marked cyanosis I have succeeded beyond expectation by combining its use with that of the anæsthetic.

Besides cyanosis other symptoms, such as the character of the *arterial pulse,* the *impulse* and *apex beat* in the cardiac area, *pallor, venous* or *capillary congestion,* the presence of *varicose veins. aneurism, œdema of the ankles and feet,* should be noted, so that the state of the circulation may be known. The quantity and character of the *urine* must be considered. Both ether and chloroform may increase albuminuria, and ether when given in large quantities and for a long time is liable to set up mild nephritis. Whether ether acts as the determining agent or only as a factor in causing suppression of urine after severe operation shock is a moot point. Certainly it is advisable to limit the

quantity of anæsthetic given if the kidneys are in any way morbidly affected.

The abdominal viscera.—In cases of "stoppage of the bowels," and of intractable vomiting from whatever cause, the anæsthetist requires to be thoroughly acquainted with the condition and to be upon the alert to obviate the dangers incident to the vomiting.

When extreme *thoracic or abdominal distension* exists, due to gaseous or fluid accumulations such as pleuritic effusion, empyema, distension of the intestines, ovarian, renal and other tumours, dropsy, or peritonitis with much effusion, there may be considerable interference not only with respiration but with circulation owing to cardiac displacement. The anæsthetic will in these cases cause increase in the dyspnœa and tendency to syncope unless the greatest care is taken. The suitable arrangement of the position of the patient's body so as to give him the easiest posture for breathing, and the very gradual administration of the anæsthetic will help to combat these dangers.

CHOICE OF ANÆSTHETIC.

ROUTINE IN HEALTHY SUBJECTS.

In the pages which follow an attempt is made to indicate which anæsthetics and what methods should be selected. It is deemed advisable to give a wide selection rather than to restrict the choice to one or two drugs and methods, since it is often impossible for the administrator to command the more elaborate apparatus required for more recondite methods. Thus those who accept Dr. Crile's views would regard his system as preferable to most others. Still, for its successful performance the technique must be exact, accurate, and conducted by an expert familiar with it, and such persons are at present few, at all events in this country.

For all *brief operations*, both in dentistry and general surgery, NITROUS OXIDE GAS may be advantageously given. It can be administered to infants and elderly people as well as to adults. Young children need especial care, as respiration is liable to stop under gas. In all conditions in which any respiratory difficulty exists, in cyanosis and in asthenic states, it is well to give it combined with oxygen, but, when that method

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cannot be pursued, nitrous oxide with air (see p. 79) gives, in skilled hands, almost as good a result, although at present the methods of administering this are less precise. As an alternative to nitrous oxide, ethyl chloride is useful for short operations. Sickness is more likely to occur after its use than after gas when administered by itself ; the choice between the two agents must depend upon whether the risk of vomiting is deemed an insuperable drawback. According to some authorities, ethyl chloride given by an open method is less subject to this criticism (Chapter VI.). With ethyl chloride, a longer and somewhat more profound narcosis is obtainable.

Sex and age. — Difference of sex is really simply that of physique and musculature, and must be considered under those heads. Ether, either in succession to nitrous oxide according to Clover's method, or following ethyl chloride, or given by itself, is the best and safest anæsthetic for general purposes alike for adults and children, and should be adopted as the routine method of producing unconsciousness before operations. Although the " open " method of etherisation is now commonly adopted, it is probable that for reasons advanced in a later chapter it is not so valuable for induction as for maintenance of anæsthesia, and should be given as a sequence to the gas-ether combination. There are, however, conditions which are often held as justifying a deviation from this routine, and these are noticed below. It may be pointed out, however, that, although apparently a long list, these conditions really represent a very small minority of cases when compared with the great number of instances in which ether should be adopted unhesitatingly. Whenever ether is to be used, a preliminary hypodermic injection of atropine (gr. $\frac{1}{150}$ or gr. $\frac{1}{100}$) should be given, provided no contra-indication is present. When this plan is adopted most of the objections formerly advanced against the use of ether disappear.

Childhood.—Infants and young children bear chloroform well, and resent having the mouth and nose covered by a face-piece, an objection, although by no means an insuperable one, to the use of ether. In many instances also ether produces much bronchial irritation in children, so that the best anæsthetics in these cases are the A.C. mixture,* or a mixture of chloroform and ether. Ether may be given to children in the following way. The ether is dropped upon a Schimmelbusch's or Skinner's mask

* A.C. mixture, one part by volume of alcohol and nine of chloroform.

covered with several layers of gauze with one ply of lint outside ; in this a " window " is cut (see p. 165). I have for years used this plan with success and satisfaction in dealing with feeble, anæmic, wasted children. I have, however, found that in most cases if you can win the child's confidence he will take nitrous oxide well, and ether can then be given in succession. Patience rather than force will usually succeed. It is important to give ether lightly, as children readily yield to its influence and require little to maintain anæsthesia. When they will not tolerate nitrous oxide, or ethyl chloride, a little A.C. mixture or chloroform dropped on a handkerchief, when a mask cannot be used, will serve to quiet them, and as soon as consciousness is sufficiently dulled ether by an open method can be substituted. A few drops of eau-de-Cologne or essence of bitter orange-peel put on the mask disguises the unpleasant smell of ether or chloroform, and is regarded by the child as " a treat." In very prolonged operations the greatest care must be taken that children are not drenched with ether ; it is unnecessary, and is liable to cause baneful after-effects. I usually give chloroform from a regulating inhaler in the later stages of a long, trying operation on children even when induction has been carried out with gas and ether or with ether given alone. This is to avoid the cooling of the body which ether produces and which is especially deleterious in the case of the young.*

Children of about five or six years of age may be given gas and ether, unless they are notably the subjects of respiratory trouble. They will probably rebel against having the face-piece applied, so that, if it be desirable to avoid " a scene," the mixture of chloroform and alcohol may be substituted and given by the open method. Although the use of chloroform is un-questionably attended with happy results in the case of children, it must be remembered that deaths from this agent are by no means confined to adults. The peculiar liability of children to fatal syncope under chloroform if they suffer from lymphatism and toxæmic changes consecutive to chloroform (delayed chloro-form poisoning—Acidosis) must be carefully considered in this connexion. It cannot be too strongly impressed upon the

* See a paper by the present writer in Report of the Special Chloroform Committee (British Medical Association), p. 51, dealing with anæsthetisa-tion of children with chloroform by the Vernon Harcourt Chloroform Regulator.

mind that children run a risk, and probably as great a risk,
in chloroform narcosis as do adults.　Children take ethyl chloride
well, although they are often alarmed by the tightly fitting mask
usual for its administration, so that it is probably better to use
this anæsthetic by an open method (*vide infra*, Chapter III., p. 88).

For the **aged,** that is for those over 60 years of age, chloroform
is often held to be preferable to ether, and in many instances such
is the case.　It is, however, true only because persons past
middle life are often the subjects of chronic bronchial troubles,
their arteries and kidneys are also frequently diseased, and so
may be injuriously affected by ether.　Old persons too, like
infants, are peculiarly susceptible to a bronchial and laryn-
geal irritability inducing distressing cough, dyspnœa, and ex-
haustion.　However, for aged and feeble subjects with weak
hearts and depressed vitality, ether, notwithstanding the above-
mentioned drawbacks, is beyond doubt the best anæsthetic;
especially is this true when atropine has been given as a prelimin-
ary, and an open or semi-open method of giving the ether is
adopted.　It often happens that when cough is at first excited
by ether a few inhalations of chloroform vapour will remove
all dyspnœa and allow the subsequent employment of ether.　In
a certain number of cases ether proves an impossible anæsthetic
for the old, however carefully it may be administered, and such
cases must be recognised and dealt with on their own merits,
the chloroform alcohol mixture being substituted.　Although
advanced age in itself does not contra-indicate the use of nitrous
oxide gas before ether, in some cases, *e.g.*, tendency to high
vascular tension with feebleness of circulation, ethyl chloride or
a little A.C. mixture may be employed in its stead as an antece-
dent anæsthetic to ether.

In **middle age,** when the patient is vigorous and muscular,
ether, preceded either by nitrous oxide gas or ethyl chloride,
should be employed, this preventing struggling, and rapidly
and pleasantly producing anæsthesia, and this is true even if
chloroform or " open ether " is adopted as soon as induction has
been completed.

Pregnant women take all forms of anæsthetics well, but
if excitable and nervous, as they are apt to be, it is better to
avoid the coughing and straining which may follow the em-
ployment of ether.　It will be found that unless very nervous,
women in this condition take nitrous oxide followed by ether

well ; as little of the anæsthetic should be given as is consistent with true anæsthesia, as it is manifestly important to avoid vomiting. An anæsthetic should not be given to a woman over eight months pregnant unless the operation is imperative. .If, however, the surgeon must operate, there is no valid reason why the anæsthetic should not be given. I have administered to women in the ninth month of pregnancy without untoward results. When women are very prone to abort, it is well, if possible, to defer both the operation and giving an anæsthetic during pregnancy. Whether the nervousness and general upset are not as much factors in producing abortion' in such cases as the anæsthetic may be questioned. Women who are menstruating can take an anæsthetic when necessary, although they are liable to "nerve storms" both in going off and coming to, and are knocked up by it. When women are given an anæsthetic during lactation the infant should be withheld from the breast if possible for twelve hours and the milk drawn off before the next feed.

ALKALOIDS GIVEN WITH · GENERAL ANÆSTHETICS.

Although the question of the employment of alkaloidal bodies in connexion with general anæsthetics will be considered in detail later, rules may be given here guiding the administrator in their use. Division of opinion exists as to which combination of such drugs should be employed, or whether one only is indicated. The ordinary contra-indications to the alkaloids obtain as a matter of course, and should such exist, the preliminary use of the substances likely to be deleterious should be omitted.

Atropine salts given in a gr. $\frac{1}{150}$ to gr. $\frac{1}{100}$ dose for adults is now practically always employed before ether, but as some persons suffer from throat dryness, the dose may be lessened if preceding experience has shown a marked action of the drug in this direction. My experience goes to indicate that gr. $\frac{1}{100}$ is usually necessary to prevent salivation and flooding of the bronchi with fluid. The best effects are produced with the following combination: Atropine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{6}$, scopolamine gr. $\frac{1}{100}$, given hypodermically one hour or one hour and a half before the inhalation is commenced. These drugs appear to antagonise

in some ways and to act concurrently in others. I think there is less of a morphine effect on the respiration when scopolamine is added, although of course the latter exerts its own specific effect. The doses given above must be modified to suit the age, physique, and general condition of the patient.

During recovery the patient needs watching, as the post-operation sleep is often prolonged and deeper when alkaloids are used. It is asserted that omnopon replacing the morphine is safer. Absolute quiet should be enforced after the injection, and the patient should not be allowed to sit up or walk to the operation-room.

CHOICE OF ANÆSTHETIC IN DISEASE.

The **imbecile, lunatics** or **persons in delirium** can be given anæsthetics and take the gas and ether sequence quite well. Any disturbance of the cerebral circulation is liable to provoke attacks of mania in persons who have once been maniacal, hence taking ether or chloroform may produce such an attack. However, the attacks do not, as far as my experience goes, always or even frequently occur after anæsthetisation.

Alcoholism.—Persons addicted to alcoholic excesses take anæsthetics badly. They usually show excessive restlessness, become much excited, and require a large amount of the anæsthetic to render them unconscious. Such persons are best given nitrous oxide followed by ether, but they often become greatly cyanosed, and to relieve this condition chloroform must be given for a time, even if ether be subsequently resumed. As a rule, oxygen given with ether prevents this cyanosis, unless the blueness is due to severe spasm. Some confirmed alcoholics remain restless and rigid even during profound narcosis. When there is no contra-indication to their employment, the use of morphine and atropine with or without scopolamine by hypodermic injection before giving the general anæsthetic will produce a better and more tranquil anæsthesia than can be hoped for without their employment.

Respiratory tract.—*Larynx, trachea, bronchi, lungs and pleural cavity.* Intralaryngeal disease demands chloroform, and the same may be said of severe affections of the trachea and bronchi, especially when the affection is acute and the dyspnœa urgent. In *diphtheria*, chloroform alone or combined with alcohol usually

gives a satisfactory result. When the asthenia is very severe it is safest to use a Schimmelbusch's mask and drop the chloroform mixture upon it. Ether may be dropped on the mask from time to time to assist the circulation, without impeding respiration. In *bronchitis* and *lung disease,* when much *cough* and *dyspnœa* exist, ether is seldom tolerated. If used at all it must be given from a semi-open inhaler, such as an Allis, or dropped upon a gauze-covered frame, with a preliminary injection of atropine. In these cases, if the patient cannot bear some mixture of ether with chloroform, such as the A.C.E., it is best to obtain anæsthesia by means of chloroform or the A.C. mixture. Ether or a mixture may be tried when anæsthesia is established, but, if ill-borne, chloroform must again be employed. As a rule, chloroform, especially when given in the A.C. mixture, from first to last is the best and safest anæsthetic when the lungs are the seat of acute or active disease. In *pneumonia* or *œdema of the lungs* ether should **not** be given under any circumstances, as it tends to embarrass the lungs still further. Chloroform may, however, be used, but must be largely diluted with air, or still better with oxygen and given preferably by a regulating inhaler. *Phthisical persons,* when the coexistent bronchitis is not severe, and cough and expectoration are not prominent symptoms, will, as a rule, take nitrous oxide and ether without discomfort or detriment. When, however, ether excites cough and causes distress, chloroform should be substituted. *Bronchitis*, if associated with *emphysema*, often causes extreme intolerance of ether, but the A.C., the A.C.E. mixture, or failing these, chloroform, will usually suit this condition. When *emphysema* is the most pronounced symptom, a difficult problem is presented. There is in most instances a dilated and weakly heart associated with it, and any anæsthetic may lead to dangerous consequences. Ether will in a few cases set up severe cough, spasm, and almost asphyxiate the patient. On the other hand, if chloroform is used, there is always a danger, unless extreme care is taken, that an overdose may be given, owing to the failure of expiratory power in the lungs and the rigidity of the thorax. The dyspnœa, spasm, and cyanosis set up by the ether will often disappear at once when the ether is replaced by chloroform. Ether, when given after atropine and by an " open " method and associated with oxygen, appears to produce less dyspnœa and spasm, and if ether is employed

this method should be given a trial. The adoption of the A.C. mixture in the later stages of the case, and care that the chloroform vapour be given very dilute, will usually bring the administration to a successful conclusion. It is in such cases that the Vernon Harcourt chloroform apparatus is most useful, as it enables the administrator to limit with exactitude the percentage of vapour at any stage of the narcosis, but oxygen should always be given *pari passu* with the chloroform.

Asthmatics as a rule take the A.C. mixture or chloroform better than nitrous oxide or ether, but when the initial degree of narcosis is passed, if but little bronchial secretion is present, ether will be well borne. Atropine must, however, be given before the administration is commenced. Asthmatics are usually relieved by nitrous oxide and oxygen, but while some patients have assured me that this combination causes a painful sensation of impending suffocation, others have asked whether it could not be given to them when their paroxysms occur, as it relieved their respiratory distress in a marked degree.

If fluid is present in the pleural cavity as in *pleurisy with effusion* or *empyema*, especially when the heart is much displaced mechanically, anæsthetics are badly borne. This arises more from the posture which the operation necessitates—commonly one which the patient, if conscious, would be unable to assume owing to cough, dyspnœa, and failure of the heart's action—than from any inherent action of the anæsthetic. In cases of pleuritic effusion, and when an empyema does not communicate with the lung, if the patient can tolerate ether there is no reason why he should not take it while the initial and only painful part of the operation of resecting ribs is performed. Usually, however, too much cough and spasm follow the use of this anæsthetic in these cases, so that the A.C. mixture or some other dilution of chloroform has to be employed. In my own practice I am in the habit of employing chloroform for most cases of lung and pleuritic disease, and have convinced myself that, upon the whole, this anæsthetic is the safest. It is best to use warmed oxygen for such patients. The use of nitrous oxide and oxygen for operations for empyema has not any advantage over chloroform, and frequently causes very grave dyspnœa and cyanosis. In any case the lighter the narcosis is, the better are the chances of the patient. The adoption of regional analgesia, blocking the nerves which supply the area

of operation is useful in very serious cases, but it is not suitable when the patient is a child or is very nervous.

It is often requisite to decide what anæsthetic will be best for persons subject to *oft-repeated attacks of bronchitis and bronchial catarrh*, even though they may be quite free at the time of the operation. If in such cases the attacks are easily excited and liable to endanger the patient's chances of recovery, ether will be best replaced by a mixture of chloroform and alcohol or by chloroform. I think that when some inhaler, such as the Vernon Harcourt, is used, so that the dose of chloroform can be kept strictly at or below two per cent., there is no doubt that, for all persons whose lungs are affected, chloroform is the best anæsthetic. When, however, chloroform is given in higher percentage it is often dangerous and should be avoided. Of course the general state of the patient must be taken into account, and the possible arguments against the use of chloroform should receive due consideration.*

I have found from the experience of past years that in cases of lung and pleuritic disease, ether, when administered well diluted with oxygen and preceded by an injection of atropine, and preferably employed by an open method, can often be taken well, provided the operation is not a long one necessitating the inhalation of a large quantity of the anæsthetic. The warming of the ether vapour is unquestionably a great advantage in all chest cases. Much of the cough, cyanosis, and distress in persons suffering from dyspnœa is caused by spasm, which is at once relieved when oxygen is given with the ether, the patient rapidly becoming anæsthetised. The oxygen further stimulates the circulation, steadying and improving the action of the heart.

I have in some very bad cases of pulmonary embarrassment employed rectal etherisation with success. Gwathmey's experience leads him to advocate colonic etherisation (ether in oil) for such patients.

Diseases of the circulatory system. — Although the existence of heart disease and vascular irregularity should materially influence the choice of the method by which an anæsthetic should be given, it very seldom vetoes the use of general anæsthesia.

* M. Lépine has shown that if the ether is pure, and is given with care, bronchitis is not increased by its use. Dr. Shipway states that ether given by the intratracheal method is well borne in the case of bronchitis.

As Snow said: "If a patient is able to undergo an operation, he will not be an impossible subject for an anæsthetic."

In **mitral disease** when the pulmonary circulation is interfered with, and some cyanosis and possibly slight œdema with cough and dyspnœa exist, ether usually increases the distress. The employment of chloroform, preferably diluted, as in the A.C. or A.C.E. mixture, exhibited from a mask and by a drop method, frequently steadies the heart. It is well to give such patients a course of digitalis before the operation, or a hypodermic of digitalin or strychnine preferably with atropine half an hour previous to the anæsthetic. The mere presence of a mitral murmur, without symptoms or failure of compensation, need not deter from the use of nitrous oxide and ether. Some authorities prefer to commence with the A.C.E. or C.E. mixture, and in such cases, if it can be borne, to give ether as soon as anæsthesia is established. I have found oxygen a valuable adjunct to ether in all cases when cyanosis existed and when the presence of œdema of the lungs did not contra-indicate ether. The state of the pulse should always be noted before an anæsthetic is given, both as a guide to the condition of the patient's circulation and also for comparison in the subsequent stages of the administration. The various causes of pulse variation must be remembered in this connexion,* and the share which respiration, cardiac action, alteration in capillary resistance and renal adequacy, and various cerebral conditions, take in affecting the rhythm, force, and frequency of the pulse should be duly appreciated. It is wise also to estimate the blood pressure of these patients. It must be remembered that in all cases of pulmonary disease, whether primary or following mitral disease, there may always be a danger when ether is given for any length of time, lest waterlogging of the lungs or œdema should arise as a later and dangerous sequela of that anæsthetic. The preliminary injection of atropine, gr. $\frac{1}{100}$, probably lessens this danger, but it does not remove it. It is, therefore, my custom, even when I commence the inhalation with nitrous oxide and ether, to change to chloroform if the operation occupies any period of time exceeding half an hour.

In **aortic disease** there is a special danger from struggling,

* "The Pulse," by Sir William Broadbent, Bart., M.D., F.R.C.P., and "Pulse Gauging," by G. Oliver, M.D., F.R.C.P., may be consulted with advantage in this connexion.

and a liability to syncope. I have found that persons so affected take nitrous oxide and ether well, but care should always be exercised to avoid any undue straining or struggling. The merit of nitrous oxide gas, preferably with oxygen, given before ether lies in the fact that struggling is avoided. The advisability of the preliminary use of morphine, scopolamine, and atropine must be discussed. This method lessens the danger of struggling, and, provided a suitable dose is given, does not interfere with the heart, while it probably protects against reflex vagal inhibition. These subjects also, as a rule, take chloroform well and this, or a mixture of it, can be given instead of gas, while ether can be employed in the later stages. Such patients, it must be remembered, are peculiarly liable to syncope as they are resuming consciousness, and the most sedulous care should be taken to prevent them from sitting up, either during the induction, or until the effects of the anæsthetic have quite disappeared. As they pass from under the influence of the anæsthetic patients may retch or vomit, and these acts are often accompanied by an alarming fall of blood pressure. In all forms of heart disease it is safer to administer slowly and warily, and to maintain a fuller dilution with air or oxygen than is necessary in ordinary cases.

Degenerations of the myocardium.—When the heart muscle has undergone structural changes, the danger of producing anæsthesia is greatly increased. It should be remembered that in severe degrees of anæmia there is evidence that the musculature of the heart presents the appearance of degeneration and loses its natural resiliency. Any alteration in the respiratory or vascular systems induced by anæsthetics imposes an extra strain upon the already weakened and diseased heart—one which it may be unable to sustain ; hence syncope supervenes. There seems also a danger, as Dr. Léonard Guthrie has pointed out, that chloroform may itself, as indeed is the case with other anæsthetics, induce a degeneration in the heart muscle in children, a grave condition when superadded to initial disease. When the heart trouble is not complicated by pulmonary engorgement, œdema or hydrothorax—when it is, in short, largely compensated —ether should be given. I am in the habit of using oxygen with ether in these cases, and find it materially assists the patient, and, I think, lessens the danger. Although it is often suggested that an open method is safer, I am not convinced that this is so,

since with a Clover's inhaler you can, by frequently removing the mask or refilling the inhaler bag with oxygen, give any degree of dilution of ether you require. This desideratum can, however, be obtained when a rigidily drop method of giving ether with a gauze-covered mask is adopted, and, given skill and experience, I regard this plan as excellent. The real danger lies in allowing the patient to inhale large quantities of ether, and " open " ether methods in the hands of those who lack experience lend themselves to this dangerous form of administration. When pronounced pulmonary trouble exists and ether cannot be borne, chloroform or the A.C. mixture may be given. In all cases when the heart is weak or irritable there is a danger of fibril-lation if the carbon-dioxide blood content is allowed to be dimin-ished. Irregular administration of the anæsthetic as well as too light a narcosis lead to this. The closed method of ether administration augments the carbon dioxide in the blood and is therefore safer at all events until the patient has become fully under the influence of the anæsthetic.

Should nitrous oxide be administered in cases of MORBUS CORDIS ? I have records of practically every form of heart disease in patients to whom I have repeatedly given anæsthetics, and among these patients, when no pulmonary disease coexisted, nitrous oxide caused no alarming symptoms. The complication of cyanosis and lung trouble with a dilated weak heart is a grave one. Sometimes nitrous oxide with oxygen is well taken, even by persons so afflicted ; but there is some risk, and the greatest care and experience are needed to bring the case to a satisfactory issue. If the patient suffers from advanced disease and the heart is working feebly, it is wise to supplement the nitrous oxide by allowing it to mix with ether vapour. This plan has in my hands answered most admirably. Warming the nitrous oxide and oxygen before inhalation materially lessens their deleterious effects and appears to enhance their efficacy, and this is equally true of ether and chloroform vapours.

Chloroform, whether pure or diluted, cannot be given to persons having diseased hearts without increasing the risk of syncope, due to the unavoidable fall in blood pressure which follows the use of this anæsthetic. This fall, however, can be minimised by using only low percentages of chloroform vapour. On the other hand, it must be remembered that in these cases the anæsthetic is in a way protective. As Snow pointed out,

chloroform "when carefully administered, causes less disturbance of the heart and circulation than does severe pain." In this connexion it should be borne in mind that shock very often killed in pre-anæsthetic days, and it is not too much to say that if chloroform is ever the cause of death when properly administered, it is certainly very often the means of saving life by protecting from pain and shock. The safety of the patient lies in using a low (*i.e.* two per cent.) vapour of chloroform and lessening its strength as the operation proceeds ; also in avoiding asphyxial complication, and this can be done by the use of oxygen.*

Hypertrophied hearts are in practice usually *dilated* hearts, and being so they are working at a mechanical disadvantage. The same rules given for guidance above will serve here. Some highly nervous, excitable persons are much terrified by the application of a face-piece, and indeed in some few cases the mental distress and terror thus excited may be sufficient to occasion serious indisposition. In cases such as these it is especially useful to employ the A.C. mixture by a drop method, replacing it by ether given by the open method when the patient is so dazed as not to perceive the change.

Vascular disease—*In arterial disease.*—In aneurism and extensive disease of arteries it is best to use chloroform or one of the mixtures containing it, to avoid the increase of blood pressure induced by ether in the initial degrees of narcosis. It is, as a rule, quite safe to give ether after the patient has been thoroughly anæsthetised and has been unconscious for some little time.† When apoplexy has previously occurred, or its onset is feared, ether had better be avoided and chloroform given. Cerebral hæmorrhage is reported to have occurred after ether had been inhaled, but the probability of such a result is slight. The danger in all cases of vascular disease arises from

* Insufficient narcosis is also dangerous, for, as Dr. Levy has shown, light narcosis—*i.e.* below the third degree, especially if the anæsthetic is given intermittently—is prone to lead to ventricular fibrillation.

† I have notes of a very instructive case bearing upon this point. The patient suffered from popliteal aneurism, for which it was proposed to tie the femoral. He was given nitrous oxide and ether, and narcosis was rapidly attained without struggling. Upon the patient being brought into the operating-room the aneurism was palpated and all pulsation was found absent. The case was cured without any operation. No doubt the increase in blood pressure had led to disturbance in the circulation, which luckily had resulted in clotting and filling up of the sac.

struggling and the consequent interference with the circulation. It is therefore most important to adopt such methods of giving the anæsthetic as will prevent or lessen the stage of excitement. This can be done by the use of nitrous oxide followed by ether, if this mixture be employed with judgment. On the other hand, there is certainly some risk in pursuing this course, since both nitrous oxide and ether tend to raise blood pressure, at all events in the initial stages of the period of induction, and this rise may be materially increased if any struggling or any other cause producing even slight asphyxia occurs. I have quoted (*vide infra*, p. 125) one case of hemiplegia follow the use of nitrous oxide and oxygen in a man with no evidence of marked arterio-sclerosis, and when no asphyxial complication was perceptible. In the present state of our knowledge I should select the following method in these cases. A preliminary injection of morphine and atropine, with or without scopolamine, and followed by chloroform and warmed oxygen from a regulating inhaler or the A.C. mixture from a mask if it were desirable to avoid the firmly fitting mask requisite for the regulator. Speaking generally, one may say that when arterio-sclerosis is present to any marked degree, chloroform is the best choice.

Congenital heart conditions.—I have given nitrous oxide and oxygen in cases of cyanosis without mishap. In major operations chloroform with oxygen is the safest anæsthetic to employ.

Renal disease.—Ether is said to produce albuminuria and even cause suppression of urine. Lawson Tait recorded a case in which ether appeared to stop the flow of urine along the ureter, which, being exposed, could be examined. Turnbull * says that Emmet of New York met with six cases in which suppression of urine occurred after operations under ether in persons with chronic nephritis. Professor Wood of Philadelphia also found cloudy swelling of the nuclei and contents of the secreting renal epithelium after etherisation of dogs. On the other hand, Eisendrath, Barensfeld, and Campbell of Montreal, found that albuminuria in human subjects was the exception after ether when previously non-existent, but that in preexisting albuminuria a slight but transient increase follows prolonged etherisation. This conclusion is fully in accord with my own experience. Chloroform is more liable to initiate †

* " Artificial Anæsthesia," 4th edit., 1896, p. 225.
† See " Complications of Ether," Chapter IV.

albuminuria according to these observers.　With the assistance of Dr. Levy I investigated this subject, and our conclusions may be stated briefly as follows * : in most cases the quantity of the urinary water was reduced, but probably not more so than could be accounted for by the abstinence from food and liquids during the period of preparation for the operation.　The solids remained practically unaffected.　When ether is given in excessive quantity ischæmia of the kidneys is produced and albuminuria results. If, however, only so much is inhaled as is needed for complete anæsthesia no deleterious results arise, and the renal parenchyma is not injured nor does albuminurià result.　The experimental work was supplemented by the study of clinical cases, and these bore out our experimental conclusions.

In **conditions of collapse,** *e.g.* railway smashes, gunshot wounds, ruptured gastric or duodenal ulcers, intestinal obstruction due to strangulated hernia, or other causes, ruptured viscera, or conditions when the vitality has sunk very low, as in the case of carcinoma affecting the œsophagus or the pylorus causing chronic starvation, also in collapse the result of severe hæmorrhage or other causes, or provoked by high temperatures, it may be necessary to perform an operation, and it will usually be desirable to administer an anæsthetic.　Ether if properly administered is, I am sure, the best and safest anæsthetic for these cases.　It may be given from a Clover's inhaler, as when that apparatus is properly handled there need be no dyspnœa or impediment to respiration.　Very little anæsthetic is required, and the mask may be taken off during inspiration every three or four respirations.　At the present time a consensus of opinion favours the use of " open " ether for such cases, and, provided due care is taken to avoid the employment of an excessive quantity of ether, as by adopting a strictly drop method with a preliminary injection of atropine, this plan offers advantages.　It is important, however, that the patient should be guarded against cooling of his body, and that the head should be kept low.　Another method of value to these patients is intravenous ether infusion.　This plan not only supplies a small and readily controlled amount of ether, but affords a ready means of supplying the saline infusion which experience has taught us is so valuable under the circumstances.　Dr. Willcox's suggestion of bubbling warmed oxygen

* *British Medical Journal,* Sept. 22, 1900 : " The Effects of Inhalation of Certain Anæsthetics on the Kidneys."

through alcohol may be used as an adjuvant measure protecting against increased shock. When there is very considerable respiratory difficulty complicating the case, the A.C. mixture may be employed. Still ether is *par excellence* the anæsthetic for such patients. It is important to give plenty of air, and only to administer the ether intermittently as necessity seems to require. I have found the use of oxygen with ether most valuable under such circumstances. In extreme collapse, *e.g.* railway smashes, the possibility of serious internal lesions and hæmorrhage must be kept in mind, as the incautious deepening of the anæsthesia may, under such circumstances, lead to serious results. A possible danger from ether in these cases arises when by increasing blood pressure internal hæmorrhage may be restarted. When the breathing is feeble and gasping, and the patient almost *in extremis*, with blue livid skin and pulseless, warmed ether vapour with oxygen should be used. It is, however, best to have only a thin gauze pad and to give the ether very sparsely, as very little anæsthetic is required. In cases of intestinal obstruction, when extreme collapse is present, I select ether and oxygen ; if, however, collapse is less marked, I prefer chloroform. In either case extreme care in regard to arranging the posture of the patient is requisite to avoid the regurgitation of intestinal fluid being aspirated into the lungs. Many authorities prefer spinal analgesia, or the recourse to local infiltration and regional analgesia for these patients. It is, however, very doubtful whether such methods are materially safer, since fæcal drowning has occurred even when they were in use. Below (see Chapter X.) a method is suggested by which the air-passages are blocked before the operation is commenced and the anæsthetic given either through an intubation tube or a tracheotomy aperture, while the stomach is continuously drained through a soft rubber tube kept in it until the operation is over. The alternative methods of **nitrous oxide** and **oxygen** or **ether intratracheal insufflation** are considered later. Of these the latter method is probably the safer.

2. The Necessities of the Operation.

Operations about the head, neck, face, trachea, and respiratory tract.—In all cases of interference with respiration due to swelling of the structures of the neck, *e.g.* angina Ludovici, enlargement of the thyroid, in cervical lymphadenoma with

pressure, nitrous oxide is contra-indicated.   Ether, if given from an inhaler, usually causes dyspnœa, and so is best avoided unless it be given by an open method; but the depth of narcosis so obtainable, although adequate for operations on the head and neck, is insufficient for cases in which the nose and mouth have to be uncovered for some minutes.   Chloroform given with great care is safest and best for the operator.   Brief operations about **the mouth, nose,** or **pharynx,** such as the extraction of teeth, excision of tonsils, opening of abscesses, snaring off mucous polypi, etc., can often be performed under nitrous oxide,* or ethyl chloride.   With nitrous oxide, from a half to one minute of unconsciousness can be expected.   In operations slightly more prolonged, ethyl chloride, and, if the cautery is not to be used, gas with ether may be employed.   In operations accompanied by severe hæmorrhage, but which do not need much time, the gas and ether sequence possesses the advantage that the patient rapidly resumes consciousness, and so the danger of blood being drawn through the trachea into the lungs is avoided.   In operations for the removal of **post-nasal adenoid growths,** I have for some years extensively used gas and ether with success, the patient being placed in the sitting posture.   It has been urged by many that nitrous oxide gas, alone or with oxygen, is a sufficient anæsthetic for the removal of post-nasal adenoid growths. This may no doubt be true for a certain number of cases, but there is a danger that the brief anæsthesia which children experience under it may prove insufficient, and so undue haste may be forced on the surgeon, and the little patient may feel the finishing steps of the operation.   Some American surgeons use gas and oxygen as a routine for these cases, but they employ morphine and atropine as a preliminary injection and maintain anæsthesia by a nasal method.   When tonsils have to be removed at the same time as the post-nasal adenoids, it is a good plan to give nitrous oxide followed by ether, and when complete anæsthesia is obtained the operation may be proceeded with, and chloroform vapour can be blown through a tube connected with a Junker's apparatus.   Thus anæsthesia can be maintained as long as is needful.   For this method the patient must be lying nearly in the horizontal posture.   Ethyl chloride answers very well for uncomplicated cases of the removal of tonsils and post-adenoid

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* The precise way in which nitrous oxide should be given, *e.g.* with oxygen, air, and so on, is dealt with in Chapter III.

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growths, but as the narcosis produced by this agent is very profound although transient, care must be taken to place the patient in such a position that the effused blood cannot be aspirated into the trachea. When the operation of complete enucleation of the tonsils is practised, many surgeons prefer the use of chloroform and ask for a profound narcosis to prevent palatine movement and rigidity of the faucial arches. This, however, can only be accomplished with a certain amount of risk, as the very nature of the operation involves some obstruction to respiration, so that the utmost care is necessary.

For most intranasal operations I have found nitrous oxide and ether following atropine satisfactory. It may be necessary in very prolonged cases to give more than one inhalation of ether, but there is no objection to this if care be taken, by turning the head to the side, that blood does not enter the lungs. When the patient is sitting up, I bend the head and shoulders forward during the reapplication of the ether. It is better to wait for a return to semi-consciousness before giving the second inhalation. When the surgeon wishes his patient to be seated, chloroform should not be given. Snow, it is true, believed that the sitting posture was as safe as any other, but there can be little doubt that in such a position the heart works at a disadvantage, and cerebral anæmia is very prone to occur. Some surgeons prefer chloroform for all patients when the naso-pharynx is the seat of operation, since they allege this anæsthetic produces (i) a more profound and lasting anæsthesia, and (ii) because less violent bleeding takes place at the time of the operation. On the other hand, the rapid resumption of consciousness under ether certainly minimises the danger of blood entering the lungs. When the operation is likely to prove a prolonged one, chloroform will be more satisfactory to the operator, but the patient must be in a recumbent position. I have adopted the plan of giving morphine with atropine, sometimes adding scopolamine before chloroform for these cases, and find that when anæsthesia is once induced, the preliminary injection enables one to maintain an excellent anæsthesia with very little anæsthetic. The drawback to this plan is that the patient remains profoundly drugged for some hours after the operation, and requires careful watching, lest, in the event of there being hæmorrhage, the blood should enter the air-passages. Prolonged operations on the mouth and air-passages are facilitated by the use of intratracheal etherisa-

tion, a valuable method but one requiring special knowledge of its technique. It is also useful for operations on the frontal sinus.

Staphylorrhaphy necessitates the mouth being open, and that the operator should have free and uninterrupted access to the buccal cavity. To effect this, the patient can be put under the influence of chloroform, and maintained so by anæsthetising through the mouth by means of a tube (as described in Chapter VIII.). The same procedure answers for operations about the **tongue.** For the removal of small growths from the tongue, lips, or from the gums, I have found nitrous oxide answers well. The method of prolonged nitrous oxide administration through the nose gives the operator a much longer period of unconsciousness. (See also Chapter III.)

In Kocher's operation for the **removal of the tongue,** ether can be used when it seems desirable until quite the end of the operation, when the mucous membrane of the mouth is opened and the tongue is dragged into the incision.

Removal of the upper jaw should, as a rule, be performed under chloroform, as the cautery is often requisite and the use of a face-piece impossible. There are, however, the alternatives of intravenous infusion of ether, rectal, or colonic etherisation and intratracheal etherisation, and the chapters dealing with these methods may be consulted for further information. In extensive removals of growths about the jaws, it is frequently advisable to perform a preliminary tracheotomy, and then give the anæsthetic through a Trendelenburg's tube, at the same time plugging the larynx. Chloroform given by a Junker's inhaler and metal mouth-tube held over the aperture of the tracheotomy tube answers well, and keeps the anæsthetic apparatus out of the field of operation. It is, however, quite possible to obtain a most satisfactory anæsthesia with ether, which allows removal of either jaw (see Chapter VIII.). I have occasionally used ether in these cases with success, and I am informed this method is employed as a matter of course in some cliniques in the United States.

In the **removal of the lower jaw,** ether may also be used for the earlier stages of the operation, chloroform being substituted when the mouth has to be opened. In any case, when the cautery has to be used, the ether must be replaced by chloroform. In asthenic, feeble subjects it is an advantage to induce anæsthesia

by an ether sequence, using atropine as a preliminary, as the ether provides a valuable stimulant, counteracting the depression of blood pressure which occurs when chloroform replaces the ether.

Operations upon the **larynx**, *e.g.* **laryngectomy,** will require preliminary tracheotomy, and in these cases I prefer to keep up the anæsthesia by a Junker's inhaler, to the efferent tube of which is fixed a catheter. By this means the amount of chloroform given can be more safely adjusted than when a Hahn's tube and funnel are employed. For bronchoscopy, chloroform or a mixture is perhaps the most satisfactory anæsthetic. In all the above cases in which chloroform is mentioned as being more convenient, alternative methods exist, namely, ether infusion and rectal or colonic etherisation.

Operations about the **eyes** are commonly performed with the aid of cocaine, β-eucaine, or other local analgesic (see Chapter XI.) ; when general anæsthesia is decided upon, and it is often necessary in the case of children and excitable nervous or asthenic persons, it is important to obtain deep narcosis. These cases require absolute immobility, freedom from coughing being essential. Nitrous oxide alone or with ether, provided the ether be pushed very far, answers well ; there is, of course, the possibility of ether exciting a fit of coughing, which, should the case be one of removal of a cataract, and should a preliminary iridectomy have been already done, may lead to forcible extrusion of the vitreous. But this can only arise when the patient is not sufficiently under the anæsthetic. There is less fear of coughing with the use of a chloroform-and-alcohol mixture. I have used the oxygen-ether method very satisfactorily for these cases. Upon the whole I think, when the patient is old and feeble, and the respiration in any way impaired by former attacks of bronchitis, that chloroform offers the best chance of a successful operation.

In **excision** of the **eyeball,** where coughing is not of such moment, ether may be used, and should be pushed to complete anæsthesia before proceeding with the operation. For passing probes or slitting up the lacrimal canals, gas is not as a rule satisfactory, as the jactitation interferes with the operator ; here the use of ethyl chloride or gas and oxygen answers every purpose by obviating involuntary movements.

For **operations** about the **thorax,** a mixture of chloroform

and ether is by some authorities considered to be more advantageous than chloroform or ether when given alone. My experience, however, is that chloroform given with oxygen, provided the dilution of the chloroform is kept low, causes less distress and provides a better anæsthesia than any other drug. For paracentesis in cases of pleuritic effusion ethyl chloride or nitrous oxide gas and oxygen is sufficient, but usually cause a feeling of suffocation. Chloroform, unless a very low percentage vapour is used, seems peculiarly liable to dangerous results in cases of empyema ; the heart is usually hampered and respiration abnormally performed ; several deaths have resulted from chloroform given in such cases. When the bronchial tubes are not blocked with pus and no communication exists between the abscess and the bronchi, ether will occasionally be well borne, but as a rule a low percentage of chloroform vapour is, I think, safer. In cases in which a plus intrathoracic pressure is requisite the intratracheal ether method appears to offer especial promise. Mr. Morriston Davies advises the employment of his plus pressure machine with chloroform given dosimetrically together with oxygen.*

It is in these operations that rectal etherisation seems likely to be of very great service. But unless atropine is used there is a danger of increased bronchorrhœa causing suffocation. I adopted this method without, however, giving atropine, for a patient at the Brompton Hospital for Consumption some years ago, and very grave filling up of the bronchi with fluid occurred. It is probable that the narcosis was too deep, and that the empyema had established a communication with a bronchus. Prompt inversion enabled the fluid to escape, and the operation was successfully completed. (See " Etherisation by the Rectum.") The choice of the anæsthetic in chest cases must depend upon whether one or both lungs contain fluid or a bronchus communicates with a large cavity filled with pus. In the latter case the fluid will collect during the night and the patient will usually empty it in the morning by coughing. After this is done the danger, otherwise very great, is reduced to a minimum. I believe chloroform or A.C. mixture is safer than nitrous oxide and oxygen or ether in all cases in which fluid exists in the lungs. Many operations on the chest, such as opening an empyema and resecting ribs, can be done under local or

* *Brit. Med. Jour.,* July 8, 1911.

regional analgesia, but the method taxes the fortitude of the patient.

Abdominal surgery.—In dissecting operations, when tranquillity of respiration is desired, some mixture of chloroform with alcohol or ether may be employed instead of ether, but for all prolonged and exhausting operations ether should be given unless strongly contra-indicated. Open ether or the intratracheal method answers admirably, especially when used after alkaloids. In all septic cases ether rather than chloroform should be selected, as evidence exists that the tissues react towards recovery far better with the former than with the latter anæsthetic. Thus, I have found for appendectomies, operations upon the stomach, intestines, and liver, as well as for Cæsarian sections, ovariotomies, and hysterectomies, ether, if carefully given, answers very well. It is undesirable to continue the ether for more than forty-five minutes or an hour unless the patient cannot take chloroform. After this time a chloroform-alcohol mixture or chloroform may be used.* Ether given by the intratracheal method reduces the thoracic movements to a minimum and so helps the surgeon. If one kidney is presumably adequate and healthy, ether may be used in nephrectomy. For operations upon the liver and gall-bladder, for those upon the intestines and stomach, chloroform or a chloroform-ether mixture makes the operation easier for the surgeon, and subjects the patient to less risk of pulmonary complications. Still, with care in the use of ether, such operations can be performed when the patient's state seems to contra-indicate the employment of chloroform. Many of the objections to ether disappear if it is associated with atropine and is given guttatim on an open mask. Very prolonged abdominal operations, if done under ether, are not free from a risk of ether after-effects, such as collapse due to over-stimulation as well as the well-recognised pulmonary dangers, so that I think it is wise to discontinue the ether as time goes on and employ chloroform, if given dosimetrically and associated with oxygen. Some authorities recommend that in practically all cases in which

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* It is alleged that ether pneumonia is especially liable to occur in abdominal operations. See " Ether Pneumonia," by Dr. David Drummond, *Brit. Med. Jour.*, Oct. 1, 1898, p. 939. This subject is discussed freely below in the chapter dealing with ether, and the reader is advised to refer to that section.

chloroform or ether is commonly used, they can be advanta-
geously replaced by nitrous oxide and oxygen, and they recom-
mend the preliminary employment of alkaloids, and at times add
ether vapour to effect muscular relaxation. It is open to question
whether nitrous oxide and oxygen protect the patient from
shock during abdominal operations or give as complete relaxa-
tion of muscles as does chloroform or ether.   When nitrous oxide
and oxygen are used it is best to give alkaloids beforehand
and to adopt Dr. Crile's anoci-association method besides
warming the gases during their inhalation. The adoption of
intratracheal etherisation, the infusion of ether, and the method
of spinal analgesia provide alternative methods.*

In labour.—There is a consensus of opinion in favour of
chloroform in these cases, but chloroform cannot be in any way
deemed more free from danger in childbirth than at any other time.
If chloroform be employed it should not be entrusted to the hands
of a nurse or other person unless skilled in its use.   The Vernon
Harcourt inhaler answers very well in these cases.   The mixtures
of chloroform and alcohol are also useful.   Ether, though
advocated by some, is disadvantageous in labour, as it may
provoke straining, coughing, sickness, and headache,† but for
general obstetric operations, and especially where the patient
is exhausted and needs stimulating, ether is indicated, and may
be given by the " open method."   I have had no experience of
the use of nitrous oxide and oxygen or of local analgesia in
labour, but the complications incident to these methods are
certainly disadvantageous. The "twilight sleep" plan is
referred to in a subsequent section.

Although no experimental evidence exists so far as I know
for the statement, yet it is commonly asserted that chloroform
is safer for the child than ether. A point worth remembering
is this, that the more agreeable smell of chloroform and its
rapidly soothing effect make the patient inhale it freely as
the pains are coming on without any holding of the breath.

* In recent years the plan has been adopted of giving alkaloids asso-
ciated with spinal analgesia and a general anæsthetic. This ensures full
muscular relaxation and the patient's insensibility.

† In my private practice I have met with cases of women who, after
trying chloroform, preferred to take ether in their confinements, stating
that it produced more exhilaration and general feeling of well-being, while
it assuaged their pangs more efficiently than chloroform.

THE PROCEDURE DURING AN OPERATION AND THE RECOVERY.

The routine to be pursued varies in the different types of operation, and is considered fully in Chapter VIII.

In every case the patient must be placed in the posture which interferes least with his breathing. If through the exigencies of the operation respiration is hampered, less anæsthetic should be given and the deficiency of air be made up for by administering oxygen. Care must also be taken that the posture does not produce pressure on nerve trunks or plexuses, *e.g.* the musculo-spiral nerve when the arm is allowed to be pressed against the side of the table or the brachial plexuses when the arms are over flexed and fastened so as to cause pressure on the cords or nerves.

The Recovery.—The patient should be kept warm and watched so that he does not turn over or assume a posture interfering with his breathing; he must not sit up, and care must be taken lest during semi-consciousness he vomits and the vomitus enters the air-passages. The maintenance of the body's temperature is essential; hence the necessity of avoiding a chill through the change of room when the patient is conveyed back to bed.

CHAPTER III.

NITROUS OXIDE GAS.

Chemical and physical properties.—Nitrous oxide (N_2O) is a colourless gas with a faint smell and slightly sweet taste.

A convenient mode of preparation is to heat dry ammonium nitrate ; the salt melts at about 165° C., and begins to decompose at about 185° C. The decomposition proceeds rapidly between 200° C. and 240° C. A well-dried mixture of ammonium sulphate and sodium nitrate is frequently used instead of ammonium nitrate because the decomposition proceeds quietly and more uniformly.

When required for anæsthetic purposes the gas is purified from chlorine (formed from traces of chlorides in the ammonium nitrate) by passing the gas through a solution of potassium hydroxide, and from nitric oxide by passing the gas through a solution of ferrous sulphate.

The vapour density of nitrous oxide is 1·5299 (air = 1), 100 c.c. of water at 0° C. dissolves 130 c.c. of the gas, at 20° C. it dissolves only 67 c.c., hence the gas is collected over hot water in order to lessen the loss due to its solubility. The gas condenses to a colourless limpid liquid at 0° C. under a pressure of 30 atmospheres. Liquid nitrous oxide can be purchased in steel cylinders. The liquid boils at —89·8° C., and freezes to a snow-like mass when allowed to evaporate; the solid melts at —102·7° C.

Nitrous oxide gas possesses well-defined anæsthetic properties, which appear to be quite distinct from the asphyxial symptoms frequently associated with its administration. This gas supports combustion when ignited bodies are plunged into it. Fifty gallons of the gas are yielded by 15 oz. of the liquid nitrous oxide. It is extremely sensitive to heat, undergoing rapid expansion as its temperature is raised. This is a point

of practical importance, since cylinders of this gas are liable to burst if subjected to undue heat; indeed this accident has occurred.

Nitrous oxide is decomposed at a red heat, but shows no tendency to undergo change at lower levels of temperature.

It has long been known that if the gas from a steel cylinder be allowed to escape suddenly, it assumes the solid form and may block the outlet. This is more liable to occur when the cylinders are placed horizontally, but when the exit tube is placed with its inner end above the level of the liquid nitrous oxide, this drawback is obviated.*

Some persons prefer the freshly prepared gas, but liquefied gas stored in cylinders gives results practically as good.

Physiological Action of Nitrous Oxide

For many years the true nature of the action of this gas upon the organism was misunderstood.

The theory that it acts by producing hyperoxidation is disproved by the fact that nitrous oxide is not split up in the tissues. A more dangerous view advanced was that nitrous oxide exercised no specific action, but mechanically displaced oxygen in the lungs and so led to tissue asphyxia. The late Sir George Johnson, following the remarkable experiments of Dr. John Reid, was led to the conclusion that nitrous oxide, by producing deoxygenation of the blood and tissues, set up arterial spasm both in the systemic and pulmonary vessels. The increased resistance to the blood-flow thus brought about led, he thought, to lividity, failure of the radial pulse, and finally through cerebral anæmia to epileptiform convulsions. Dr. Amory of Boston also held this view. Professor H. C. Wood,† assisted by Dr. David Cerna, has made important observations on this subject. Their paper must be consulted for details; their conclusions alone can be briefly noticed here. They regarded the action of nitrous oxide and nitrogen as similar, but found that nitrous oxide produces anæsthesia probably more rapidly, and does so by "shutting off the oxygen." Although no reference is made to the experiments which were made by me some years before their paper was published, their

* See Dr. Sheppard's paper, *Lancet*, Feb. 21, 1891.
† *Therapeutic Gazette*, Aug. 1890.

conclusions with regard to the circulation of the blood under nitrous oxide are very strikingly in accord with mine. "It would seem," they say, "as though nitrous oxide acts upon the heart and nervous system directly, but has little or no direct inherent influence upon the vasomotor centres or the brain cortex." In comparing the effects of these gases with those brought about by asphyxia, it is admitted that the resemblance, which so many preceding observers had erroneously regarded as identical, is only noticeable to a certain extent. There is little doubt, however, that, in the observations cited, insufficient care was taken to discriminate between the phenomena due to a deprivation of oxygen and those due to nitrous oxide given without any associated asphyxial complication.

If oxygen is excluded for too prolonged a period, of necessity the phenomena of oxygen deprivation will make themselves manifest. If, as has been assumed, no anæsthesia can result until this oxygen starvation exists, the question is settled; but such is not the case. Indeed the classical experiments of Paul Bert proved this. Further, I was able to confirm this experimentally in my research,* undertaken in 1885, and Wood and Cerna subsequently undertook their experiments with nitrous oxide mixed with oxygen. When the supply of oxygen is carefully regulated the most profound anæsthesia associated with normal pulmonary and systemic circulation results. Under these circumstances no question of tissue deoxygenation arises, so that it must be admitted that however asphyxial conditions may, through want of expertness, play a part in some forms of nitrous oxide anæsthesia, yet the gas in question certainly possesses a specific effect upon nervous tissue and exerts that influence through the blood. This statement is supported by my experiments referred to, as it was shown by them that the brain tissues were affected by nitrous oxide without there being similar changes engendered by asphyxia.

Nitrous oxide appears to suspend rather than abolish function. Seeds will not germinate but remain uninjured when kept in it for an indefinite period. Seeds, if sprouting, cease to develop when placed in an atmosphere of this gas, but resume their growth when again placed in the air. Jolyet and Blanche found that plants placed in nitrous oxide gas cease to absorb carbon

* *Transactions Odontological Society*, vols. xviii. and xix., on the "Physiological Action of Nitrous Oxide Gas."

dioxide, and do not increase in size. When oxygen is allowed
to mix with the nitrous oxide the seeds germinate, and the plants
grow. Cold-blooded animals die in an atmosphere of nitrous
oxide in about two hours. This contrasts with what obtains
when the same creatures are placed in indifferent gases, such
as hydrogen or nitrogen, for under these circumstances death
does not occur for three hours, and is preceded by stupor but not
true anæsthesia. Kappeler has shown that frogs placed in nitrous
oxide lose reflexes after a very few minutes, whereas the reflexes
persist for several hours when the frogs are placed in an indifferent
gas, *e.g.* nitrogen (Goldstein). Sir Humphry Davy, in his care-
ful research, showed that small mammals and birds soon die
in nitrous oxide, although when it is mixed with oxygen they
live until the oxygen tension sinks to six per cent., as against a
carbon dioxide tension of twelve per cent.

Animals placed in non-respirable indifferent gases become
convulsed before death ; this does not obtain when they are
made to respire nitrous oxide, provided asphyxial conditions are
not present. Their respirations simply grow more and more
shallow, and finally cease without any of that *besoin de respirer*
which is elicited when simple deprivation of oxygen is practised.

Krishaber, experimenting with rabbits, found a marked
acceleration of the rate of the pulse, with increased force at
first in the heart-beat. Subsequently when anæsthesia was
induced some retardation occurred, while the cardiac rhythm
became less regular. Respiration was accelerated, and death
resulted in two or three minutes. He performed control experi-
ments by ligaturing the trachea. In these, cardiac rhythm
remained unchanged until after the fourth minute, when the
heart-beats grew irregular, and ceased at times varying from
seven to eleven minutes. The animals remained sentient to
the very last. I have repeated these experiments, using dogs
and cats in preference to rabbits, because these last are peculiarly
liable to fright, and fear disturbs the rhythm alike of the heart
and respiration, and in the main my results agree with Kris-
haber's. While dogs die in from two to three minutes in nitrous
oxide, they do not succumb to asphyxia for five ; under nitrous
oxide they grow wholly insentient in from fifteen to thirty seconds,
while in asphyxia consciousness of pain only ceases with life.
Under nitrous oxide I found the heart little affected except
for an initial stimulation until the respiration was gravely in-

terfered with, in other words until asphyxial conditions were present, and then it gradually failed before totally stopping. The creatures seemed under the gas to sink into sleep, and from sleep to pass into death, whereas when asphyxiated they struggled from first to last.

In the human subject.—It is probable that nitrous oxide, when administered pure, enters the blood by diffusing through the thin walls in the air-cells in the lungs. In the blood a small quantity is dissolved, but the bulk is aggregated in some loose way with the blood constituents, probably being associated more or less closely with the proteins of the liquor sanguinis and corpuscles. Pickering has, in an interesting research, corroborated the view which was suggested by me in the papers referred to above, that nitrous oxide is taken into a loose association with the hæmoglobin of the blood.* Dr. G. F. Kemp † of Baltimore has performed experiments which support the views I advanced in 1885 (*vide supra*). According to Herman, nitrous oxide destroys the red blood corpuscles. Turnbull, however, has experimentally shown that the corpuscles do not give evidence of any change after inhalation of nitrous oxide. I myself, by carefully watching the corpuscles in the web of a frog's foot, while the frog was in a bell-jar of nitrous oxide, was able to observe not only the phenomena of the circulation under these conditions, but also to satisfy myself that no breaking up of corpuscles was evident. The actual changes in the gases of the blood under nitrous oxide were examined by Dr. Thomas Oliver ‡ and Mr. F. C. Garrett, but they, like other observers, do not seem to have been sufficiently careful to obtain an analysis of blood charged with nitrous oxide but yet not so deoxygenated as to be practically asphyxial blood containing nitrous oxide. Their results are :—

(Normal Dog.)		Before Inhalation.		After.
Carbon Dioxide	..	34·3	..	15·66
Oxygen	..	22	..	3·49
Nitrogen ..	..	1·8	..	11·23
Nitrous Oxide ..	..	—	..	22·49

* *Cf.* the theory of the aggregation of chloroform with the erythrocytes of blood advanced by Moore and Roaf (*Proc. Roy. Soc.*, vol. lxxiii., p. 459).
† *Brit. Med. Jour.*, Nov. 21, 1897.
‡ See *Lancet*, Sept. 23, 1893, p. 683, for Dr. Oliver's conclusions.

The effect of shaking arterial blood with nitrous oxide gas *in vitro* is to darken it, showing that nitrous oxide gas is able to displace oxygen. But whatever union does take place between this gas and the blood constituents is very unstable, since blood parts at once with its nitrous oxide when left in free contact with oxygen or air.

RESPIRATION AND CIRCULATION

Under prolonged inhalation of nitrous oxide, the respiration becomes slowed and shallow, and, if the gas be pushed, a complete cessation of respiratory movements eventually takes place. The amount of tissue change is lessened, hence the quantity of carbon dioxide which the lungs give off is diminished. Subsequently to the administration, the exhalation of carbon dioxide is increased. The **heart** beats quietly, fully, and regularly under this gas ; the pulsations are somewhat slowed in profound narcosis. Healthy persons incur but slight danger of heart failure from its inhalation. In animals killed by nitrous oxide gas, the heart goes on beating even after the respirations have quite ceased. It is, therefore, less important to watch the pulse than the respiration. Blood pressure is somewhat increased, and markedly so in the brain and cord, the vaso-motor system of different areas being, it would appear, diversely affected. This altered pressure is, however, usually but slight. Dr. George Oliver has made some important observations upon the variations in blood pressure under anæsthetics. By the use of his arteriometer, he found that when nitrous oxide was given alone, if it were pushed to a stage in which asphyxial symptoms began to show themselves, it caused " a slight expansion of the calibre of the artery followed by a reduction either to the normal calibre or to a point or two below it," although " the drop below the normal need not take place," *i.e.* when a simple nitrous oxide effect occurs. . When oxygen is given with the nitrous oxide no reduction of the normal calibre takes place.

The rise of blood pressure under nitrous oxide, although slight, may become much accentuated if any asphyxial factor is allowed to intrude. This is a very important matter to bear in mind when the patient suffers from an abnormal height of blood pressure, *e.g.* in cases of arterio-sclerosis.

In some observations I made upon this subject, I found that

nitrous oxide produces sufficient expansion of the brain and cord
to force out the cerebro-spinal fluid.   There can be no doubt
that these changes are vaso-motor in origin, and explain many
of the nervous phenomena elicited in persons narcotised by
nitrous oxide.

Nervous System

The special senses of a person passing under nitrous oxide are
at first rendered somewhat more acute, after which follows a
condition of analgesia.   During the first degree of unconscious-
ness a loose tooth may be extracted without pain, although the
patient has a vague idea that something is being done.   A few
seconds later, and the individual is profoundly unconscious
and insensible of his surroundings.   Irregular discharges of
nervous energy frequently show themselves at this stage in jacti-
tations of the arms and legs.   These movements are probably
due to the deprivation of oxygen, as the admixture of air or oxygen
before they develop effectually prevents their appearance.   If
nitrous oxide gas continues to be respired and oxygen is excluded,
the limbs become rigid, the rigidity being every second or two
broken by a sudden contraction of the flexors.   Rhythmic tremors
of hands and arms are occasionally elicited.   More rarely the
whole body of the patient arches backward like a bow (opistho-
tonos).   Mr. Clover recorded a case of an adult who in this way
jerked himself completely out of a dental chair.   This condition
is especially liable to occur in children.   The muscles relax to
some extent when asphyxia is relieved.   The degree of rigidity
and the amount of jactitation vary in different cases ; children
show jactitation early, and the movements of the limbs are more
marked in them than in adults.   The superficial reflexes are
abolished, that of the patella tendon, however, persists ; and
in many cases ankle clonus is developed under nitrous oxide.*
The pupil usually undergoes wide dilatation when complete
anæsthesia is attained, but this phenomenon is not absolutely
constant and is not an indication of danger.   The eyeballs seldom
become fixed and conjunctival reflex is not invariably lost, so
that " ocular phenomena " are an unreliable guide in judging
whether anæsthesia is developed.   Nitrous oxide mixed with

* For further particulars on this point see a paper by the author on
" Ankle Clonus under Nitrous Oxide," *Brit Med. Jour.*, Sept. 24, 1887.

air or oxygen causes no muscular movements. Nitrous oxide associated with oxygen, when given through long periods as in surgical operations, is apt to induce a stiffness, sometimes amounting to rigidity, which constitutes an objection to its use for prolonged operations. It has been shown that the elimination of carbon dioxide is lessened during the inhalation of nitrous oxide, so that it is only reasonable to expect some effects of accumulation of this gas in the blood and tissues. It is probable that "a process of internal asphyxia," *i.e.* tissue asphyxia, may occur when insufficient oxygen is given *pari passu* with the nitrous oxide.*

During the condition of hyperæsthesia which precedes anæsthesia, the patient is often affected by hallucinations, frequently of an erotic nature, and the impressions then received remain impressed upon the brain. The difficulty of convincing persons that such impressions are not realities should lead every administrator to secure independent evidence of his actions while his patient is unconscious. The bladder and even the rectum may be involuntarily emptied under nitrous oxide, especially in the case of nervous persons, or if the anæsthetic is pushed, and hence it is always wiser to allow patients to void urine before taking this anæsthetic. As a rule, the alimentary tract is unaffected by nitrous oxide, but nausea, vomiting, and bilious derangement may occur after its administration. In view of the possible occurrence of this trouble, it is well for patients to abstain from food for an hour or so before taking nitrous oxide gas.

Later effects, which are said in some instances to ensue from the gas, are various functional derangements of the nervous system, tinnitus aurium, headache, and amaurosis; but these conditions occur only with the most exceptional rarity.

Laffont, arguing from a somewhat limited number of cases, considers that the effect of nitrous oxide is to produce untoward complications (1) in pregnancy, (2) at the menstrual epoch, (3) in persons subject to nervous disorders, (4) in diabetes, on account of the prejudicial effects of deprivation of oxygen in these conditions. As will be pointed out later, his contentions are fully met if we adopt the correct method of giving nitrous oxide, which is to avoid any asphyxial complications.

It may be said generally that our present knowledge of the

* *West London Medical Journal*, 1899, p. 204.

physiological action of nitrous oxide goes to show that that agent has not any deleterious action in itself. It is a heart stimulant, and is free from any irritant action on the lungs ; it does not interfere with the functions of digestion or of the kidneys, but if given without sufficient care or knowledge bad results may accrue through the supervention of symptoms due wholly and solely to the accompanying but unnecessary deoxygenation of the blood and tissues. The fact that nitrous oxide given with oxygen is less safe when administered for a long time for major operations is probably due to the necessity in the latter case for delimitation of oxygen, as well as the practice of rebreathing, and the greater interference with pulmonary blood circulation.

Duration of anæsthesia.—The induction period of anæsthesia by nitrous oxide varies, but is usually about 55 seconds. The duration of anæsthesia is for anæmic persons and children about 30 seconds, for adults 40 to 45 seconds. When given with air or oxygen, the duration of workable anæsthesia is longer, often 50 to 60 seconds, since the operator can depend upon immobility throughout the whole period of unconsciousness.

The greater the amount of gas inhaled, the longer will be the period of anæsthesia, so that, provided the patient is respiring freely all the time, a longer period of induction leads to a longer anæsthesia. Persons with a large vital capacity take most, children, feeble and anæmic people least, these last come rapidly under the influence of the anæsthetic, and as rapidly resume consciousness. Such people are good subjects for nitrous oxide combined with air or oxygen, as it allows them to inhale sufficient of the anæsthetic to render their blood saturated to the required extent for an effective anæsthesia.

CHOICE OF METHOD OF GIVING NITROUS OXIDE FOR VARIOUS OPERATIONS.

For very brief operations, occupying less than half a minute, nitrous oxide may be given by mouth inhalation. When the patient is weakly, anæmic, cyanosed, or congested in appearance, or is a child, it is better to employ mixtures of nitrous oxide with air or with oxygen. These mixtures are also better for operations requiring more time, as usually an additional ten seconds or so of available anæsthesia for operating are thus obtained. In longer dental operations the nasal method gives

5

as much time—ten or fifteen minutes in favourable cases—as
is usually needed. The alternative methods for such prolonged
operations are : nitrous oxide followed by ether ; ethyl chloride
by itself, or given with nitrous oxide. Nitrous oxide, with air
or oxygen, can be given for major operations, even those upon
the mouth, nose, and oro-pharyngeal area. These require a
special apparatus and technique, and are dealt with later.

In Dental Surgery.

Nitrous oxide alone, or combined, is the safest and in most
cases the best anæsthetic for this branch of surgery. When nitrous
oxide is used alone, and pushed to the point of stertor and jactita-
tion, two or three teeth may be extracted at one sitting, and
expertness in operating may, in some cases, enable many more
to be removed. Abnormality of the teeth or mouth may render
extraction so difficult as to prevent the successful removal of
even one tooth at a sitting, and in all instances it is better not to
promise the extraction of several teeth unless the case is mani-
festly an easy one. The operation should never be continued
when the patient is becoming conscious, otherwise he will com-
plain that he perceived the removal of every tooth ; to obviate
such mishaps, an operator would do wisely to place himself in
the hands of his anæsthetist, who will generally be better able
to judge how much may be done with impunity. Unless some
special reason exists for desiring to extract several teeth at one
sitting, it is advisable to let the patient attend twice or thrice
rather than to subject him to more than one administration on
the same day. Extracting a number of teeth simultaneously
produces more or less severe shock, and should therefore be
avoided when possible. When it is necessary to perform an
extensive operation at one sitting, one of the plans suggested
below may be adopted.

Nitrous oxide may be given—

    By inhalation from a bag through a valved face-piece.
    By the " open method " (Flux).
    By mouth injection (Coxon).
    By nasal methods.
    In combination with oxygen.
    In sequence with ether.
    In sequence with ethyl chloride.

THE ADMINISTRATION OF NITROUS OXIDE GAS.

.The simplest apparatus employed consists essentially of one or two cylinders of compressed gas placed horizontally. The cylinders are made to hold either 100 gallons, 50 gallons, or 25

FIG. 1.—Yoked nitrous oxide cylinders with Cattlin's bag, face-piece, and metal valved connexion supported on stand.

gallons. Roughly 50 gallons of N_2O may be taken as weighing 15 ounces, so that, knowing the weight of the cylinder when empty, the amount of gas remaining in the cylinder can be readily read off by weighing the cylinder. The two cylinders are yoked together by a connexion the free end of which is screwed to a

further metal mount carrying a length of tubing which is attached to the gas-bag, at its distal end. This tubing may be made of metal or of rubber strengthened by coiled wire to obviate kinking or compression if trodden upon, as, if this occurs, the rubber tube will burst and the noise of such a happening will alarm the patient.
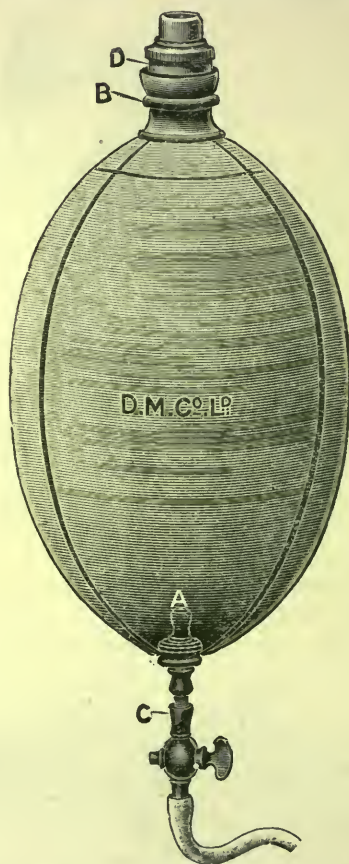

Fig. 2.—Mr. Vernon Knowles's reversible bag.

To prevent the noise of the outrushing gas, a "silencer" is sometimes attached to the yoking connexion. This is usually unnecessary, as a little care prevents the hissing of the escaping nitrous oxide. The gas-bag (Cattlin's bag) is made of rubber and should be capable of containing two and a half or two gallons of gas. The face-piece, which should fit accurately, is connected

with the gas-bag by a metal mount fitted with both inspiratory and expiratory valves to prevent the patient's exhalations fouling the bag. Mr. Vernon Knowles has devised a reversible bag (fig. 2) which can be turned inside out after washing and sterilising, so that each patient breathes into a sterile bag. When tuberculous, syphilitic, or other obviously septic persons are concerned, it is wise to employ an all-metal face-piece instead of the usual rubber one, since the latter cannot be boiled without destroying it (see fig 3).

The two stopcocks figured below are simple and allow easy access to the valves, which is essential, since all rubber material is apt to perish unless constantly in use, and unless kept at a
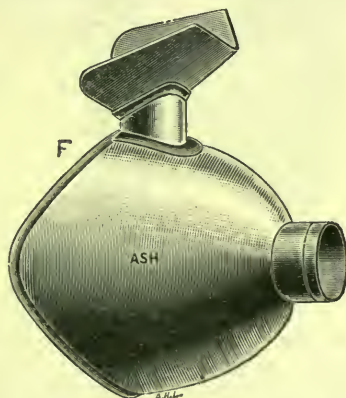

FIG. 3.—All-metal aseptic face-piece. (Weller's.) For septic cases.

moderately warm temperature (figs. 4 and 16). It is useful to powder the bag, the face-piece, and so on with French chalk and boric powder after cleansing, as this obviates the rubber sticking together and maintains a smooth surface.

When the gas supply is taken from a large gas container this is connected with the bag and face-piece by an adequate length of tubing.

After use the cylinders should be carefully examined to ascertain whether the exit is fully closed. Any escape may be detected if a film of water be smeared over the outlet, since, if there is any escape of gas, a bubble will form.

The most convenient shape of cylinder is that with an angle attachment provided with a foot-piece (fig. 1). This latter is usually more under control than is the case when a hand-key is

used.   Various mechanical contrivances have been made which
obviate the turning on the gas supply by rotating the foot-piece,
but they are hardly necessary except perhaps for hospital use.

A few words may be said about face-pieces.   Personally, I
prefer those made of rubber, of the shape designed originally
by Clover, and furnished with an air-cushion (fig. 4).   Three
sizes are usually required—one for children, also a medium, and
a large.   If an expiration valve exists in the stopcock of the
mount attached to the Cattlin's bag, none is required in the
face-piece.   Celluloid and metal face-pieces (figs. 3 and 16) fitted
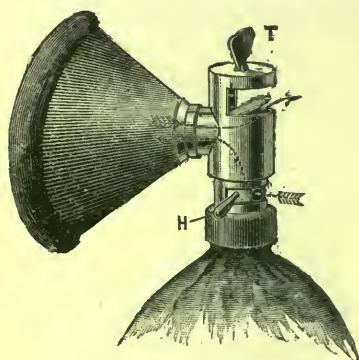with removable air-cushions are not satisfactory, as after a little

FIG. 4.—Face-piece, stopcock, and gas-bag for the administration of
nitrous oxide gas only.   (Hewitt's apparatus.)   The handle, H, opens
or closes the air-way, while it closes or opens the supply of gas from the
bag.   The tap marked T when rotated closes the expiratory valve and
allows of rebreathing.   The arrows indicate the course followed by air
or gas.

use the cushion does not apparently prevent a leakage of gas
or air.   The advantage claimed for the celluloid mask is certainly
actual—it allows the anæsthetist to see the mouth of the patient,
and so enables him to detect vomiting or other untoward accident.
The metal face-pieces can be sterilised by boiling, the rubber
ones by immersion in lysol or carbolic acid solution after careful
cleansing.   They should be rinsed out in boiled water after
sterilisation, as the antiseptic, if left on the rubber, may affect
the skin.

SUBSIDIARY REQUIREMENTS.

Gags, mouth-openers, dental props, tongue-forceps, oral spoon,
a tracheotomy case, sponge-holders, tincture of iodine, and

sterilised mops should always be at hand before the administration commences.

Gags.—The one figured has special advantages from the facility it offers for rapid removal and replacement. In it the screw-fixing arrangement is replaced by a ratchet.

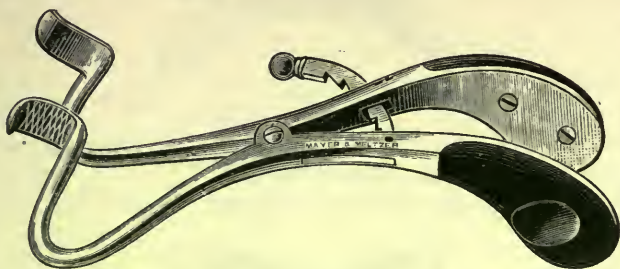By putting the finger upon the free end of the ratchet and

FIG. 5.—Gag fitted with ratchet arrangement. (Dr. Dudley Buxton's pattern.)

pressing it backwards as one does a trigger, the ratchet is released and the gag closes. To open it, it is only necessary to press the handles together and the ratchet will automatically gear and prevent closing of the mouth. The ratchet arrangement can be used with long or short handles; personally I prefer the latter. With long handles such powerful leverage is obtained that teeth may be easily forced out of their sockets or snapped off if they are at all brittle. If the jaws of the gag (W. B. Ackland) are placed on the same plane, the gag is more easily introduced but is more liable to slip.

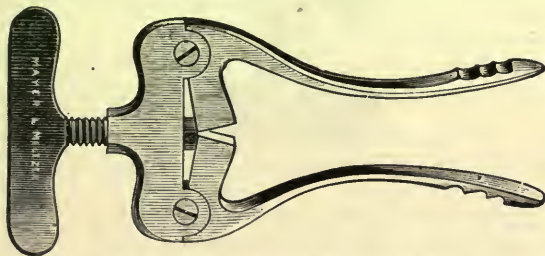Of mouth-openers, Heister's, figured below, is the best. It

FIG. 6.—Mouth-opener. (Heister's.)

possesses enormous power, so it must be used with care. Its employment is indicated in cases of severe trismus, partial

ankylosis, etc. The blades may be inserted either in a gap
caused by the previous extraction of a tooth, and, if possible,
between the molars. If placed between incisors great risk is
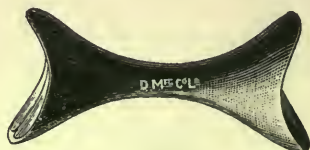run of forcing these teeth out of their sockets. Various mouth-

FIG. 7.—Vulcanite mouth-prop. (Dr. Dudley Buxton.)

openers made of wood or metal, tapering so as to act as a wedge,
are in use, but need no special mention.

Dental props.—Mr. Clover employed those made of hard

FIG. 8.—Mouth-prop. (Underwood.)

wood, but, although very convenient and not liable to slip,
they are apt to get chipped and split.

The cleanest and nicest I know are those figured (fig. 7) and
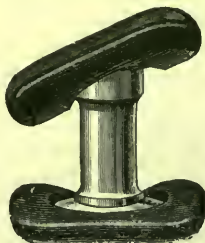made of vulcanite. The shank is strengthened by a metal

FIG. 9.—Mouth-prop. (Hewitt.)

tube, about which the hard vulcanite is placed. The ends are
ridged and grooved to prevent slipping.

The mouth prop spoken highly of by Mr. A. S. Underwood
and figured above is also useful. It has a soft pad at either
extremity (fig. 8).

Although spring and mechanical props are objectionable upon the general ground of their liability to get out of order or to break, yet some kinds are useful, and I subjoin illustrations of some of the best.

The props shown in fig. 9 are serviceable. They are made of metal, shaped to fit between the upper and lower teeth, and have removable india-rubber caps on their extremities. Except in cases in which the wedge has to rest on the gum, I think the rubber caps are undesirable, and prefer to employ props of the same shape as the one figured made wholly of nickel-plated
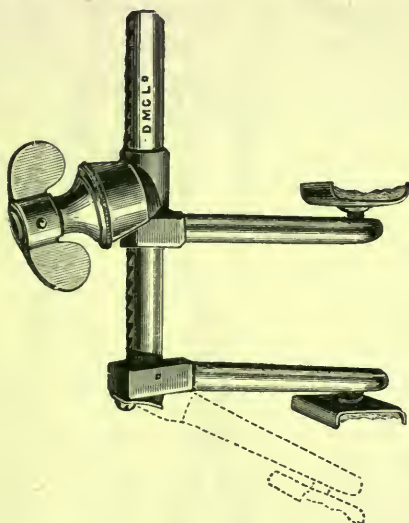

FIG. 10.—Central gag. (Weller.)

metal, with the surfaces cupped to hold a biting surface of lead. This, although it does not chip, allows the teeth to grip slightly into it. The narrow end of the wedge is placed towards the pharynx, and the horizontal surface should rest on the mandibular teeth.

A central prop, fixing upon the anterior teeth with a rotating arm, permits of operations upon one or other side of the mouth according to the necessities of the case. A very convenient form is figured above (fig. 10). It possesses an easily working screw, which permits of very nice adjustment. The plates should rest upon more than one tooth in each jaw.

No mouth prop or cork should be placed in the mouth without

being first securely tied to a counterpoise which hangs out of the mouth, and prevents the prop becoming wedged in the larynx or œsophagus in the event of its slipping. Several sizes are
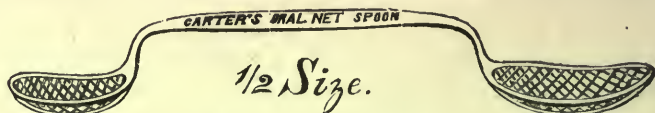

FIG. 11.—Mouth-spoon.   (Dr. Dudley Buxton's pattern.)

required, and these can be carefully tied together with strong fishing cord ; the chains often used are apt to snap. The few minutes spent in carefully adjusting the prop between the
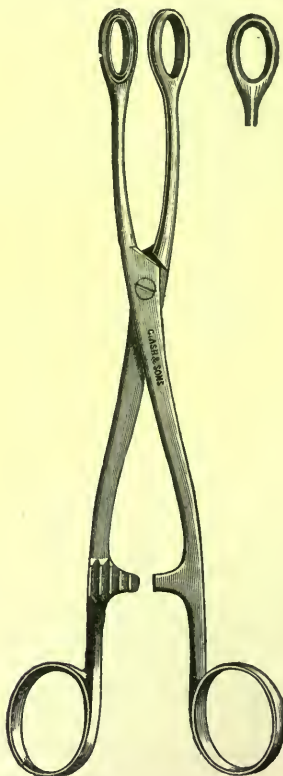

FIG. 12.—Tongue-forceps.

teeth should not be grudged, as the after success of the operation depends largely upon the security obtained by this manœuvre.

It should be adopted as a general rule, when possible, that the dental prop should be placed not farther forward than the premolars.

The mouth-spoon (fig. 11), made for me by Messrs. Ash, is safer than Mr. T. S. Carter's original pattern, in which the shank of the spoon is liable to separate from the bowl with
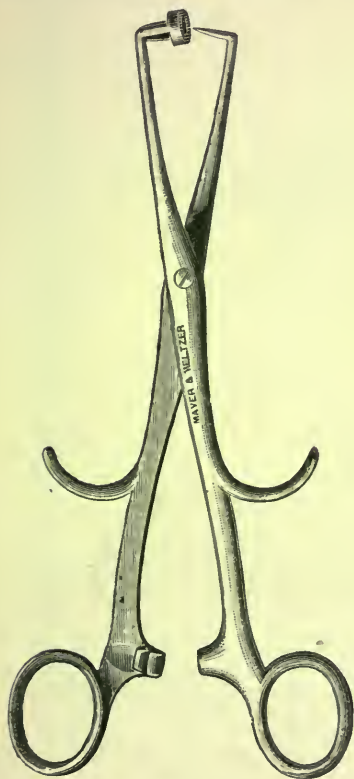
FIG. 13.—Tongue-forceps.
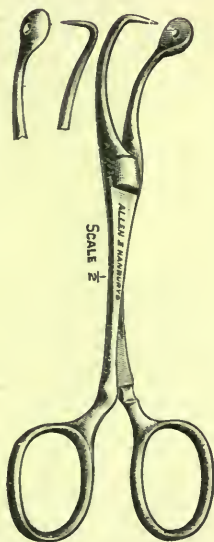
FIG. 14.—Dr. Kingsford's tongue forceps.

obvious risk. By carrying the shank to the distal end of the bowl, as in my pattern, this danger is obviated. The use of the oral spoon is to catch any teeth or roots which may fall out of the forceps. Lower premolars are especially apt to spring out of the beaks of the tooth-forceps during an extraction. The spoon is held below the seat of operation, care being taken not to allow it to get in the way of the operator.

The **tongue-forceps** (figs. 12 and 14) need no special description. Some prefer to use an instrument which pierces the tongue, as the punctured wound is believed to heal better than when the tongue is crushed. Dr. Kingsford's tongue-forceps (fig. 14) is the most convenient form.

A **tracheotomy case** containing sterilised instruments should always be at hand when an anæsthetic is to be administered.

It is important to have the apparatus ready for use and portable. The figure below shows a bag designed by me for
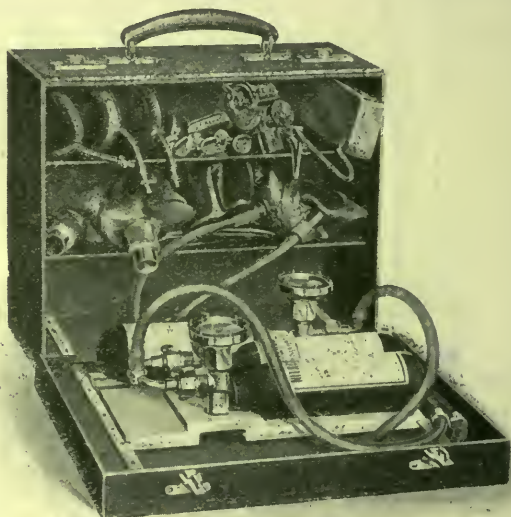
FIG. 15.—Nitrous oxide case.

this purpose. Props and instruments should be kept in metal cases, and face-pieces in metal holders.

Administration of nitrous oxide for dental operations.—The posture of the patient is a matter of importance (see Plate II.) It is essential that he should be so placed that he is at perfect rest, his muscles relaxed, and his breathing and circulation quite unimpeded. To achieve this he is seated in a chair, his body slightly extended on his pelvis, the legs hanging freely and not pressed against the foot-rest. When the legs are long the feet should touch the ground one on each side of the foot-

PLATE II.

Pose of patient during the administration of nitrous oxide gas. The anæsthetist is placed behind in order to show the position of the patient and the face-piece. Normally he would use his left hand to hold the face-piece, not his right as shown in the figure, and he would stand on the left of the patient.

rest. The head should now be in a line with the trunk ; any marked degree of flexion or extension not only causes discomfort, but actually interferes with normal respiration. If the exigencies of the operation require any deviation from the natural pose of the head upon the shoulders, it is best for the anæsthetist to hold the head in the required position *after* the patient has become unconscious, and to restore it to its normal position as soon as possible. Thick-necked and stout persons should be most sedulously guarded against malposition as well as from the effects of pressure about the heart or the abdomen. Ladies suffering from slight goitre often disguise the deformity by a lace necktie. It is always wise in view of this to have such neckties undone, so that the anæsthetist may at once see whether any cervical swelling exists.*

The apparatus having been tested to see that the valves are working properly, and that the gas enters the bag freely, the dental prop may be then placed in position. It must be carefully fixed in the opposite side of the mouth to that upon which the operation is to take place, and a glance cast round the mouth for artificial dentures, or an obturator, which, if present, must be removed. Weak or broken-down teeth should be noted and avoided in fixing the dental prop, and in the subsequent use of a gag. The administrator usually stands to the left of the chair, having the stand with the cylinders of nitrous oxide to his right and a little behind him. The gas-bag should hang freely down to the left of the patient's chest. The patient is now to be reassured by a few encouraging words, and directed to breathe naturally. It is well to allow a nervous subject to take several very deep inspirations before applying the face-piece, as these clear the lungs and divert the attention from a supposed horror of "taking gas." The Cattlin bag is partly filled by turning the toothed foot-piece under the foot from right to left. The gas must be allowed to leave the cylinder intermittently, as if permitted to flow continuously and rapidly ·

* A case in my practice emphasises this point. The patient was obviously a little breathless on entering the room, and to my question said she " suffered with her heart." The tachycardia suggested goitre, which was looked for and recognised, and measures taken to meet the exigencies of the case. The dental surgeon remarked to me afterwards that a death under nitrous oxide had occurred in his hospital, the patient being affected with goitre, which had been unnoticed before the anæsthetisation.

it is liable to freeze and block the exit.   The face-piece is then
lightly applied to the patient's face, and retained by just sufficient
pressure to prevent the escape of the nitrous oxide or the entrance
of air around the air-cushion.   The face-piece should be held
by the left hand of the anæsthetist in such a way that the thumb
is placed across the mask above the attachment, the first finger
parallel to the thumb should rest across the mask below the attach-
ment, and the remaining fingers should support the patient's
jaw, exerting a steady upward pressure of the face into the face-
piece, while the forefinger and thumb steady the mask and
maintain its due and accurate apposition to the face.   Although
no great force must be used it is essential that no air enters beneath
the air-cushion.   This in-leakage is most apt to occur at the root
of the nose and buccal regions, especially if the cheeks are hollow
through loss of the normal buccal fat pads which should give the
contour to the face.   In a second or two, the patient becomes
accustomed to the face-piece, and the administrator is able to
learn that the valves act properly.   At the instant of inspiration
the stopcock is turned so that the patient inhales the nitrous
oxide from the bag.   During the administration this is kept
nearly full of gas, by rotating the foot-piece from right to left.
It is well to open the ingress way of gas during inspiration and
close it during expiration.

After the first fifteen or twenty seconds, that is, after the
lungs are presumably filled with nitrous oxide, and when gas
is gaining tension in the blood, slight duskiness of the skin
appears, the ears and finger-tips darken ; consciousness, how-
ever, is usually present for ten or fifteen seconds longer.   In
half a minute the patient's power of receiving impressions and
reasoning upon them is greatly interfered with, and soon all
consciousness is lost.   At this stage, incautious acts, such as
touching the conjunctiva, making loud noises, or roughly hand-
ling the patient, may lead to his completely regaining conscious-
ness.   In about forty-five seconds after the application of the
face-piece, the pupils will usually dilate, the eyes becoming dull
and expressionless, while squinting may occur.   The conjunctival
reflex will persist, and, if the face-piece be removed now, the
return to consciousness will be rapid.   There is at this stage, as
a rule, time for the extraction of one tooth, if fairly loose.   When
the inhalation is not checked at this time and if no air is admitted,
further signs of deeper narcosis appear.   The breathing grows

stertorous,* muscular movements of the hands and feet supervene, and the conjunctival reflex becomes sluggish, or disappears. The patient is now ready for operation, and it is not wise to attempt to push nitrous oxide beyond this point.†

METHODS WITH MIXTURES OF AIR AND NITROUS OXIDE.

The actual period of anæsthesia varies in length directly as the amount of gas absorbed into the tissues, and in order to obtain the maximum nitrous oxide tension in the blood deprivation of oxygen (tissue asphyxia) must be prevented. When oxygen gas is not being employed with nitrous oxide in the manner described below, air may be admitted from time to time. If, for example, after a brief induction duskiness appears and the muscles about the eye begin to twitch, or jactitation of the limbs occurs, the valve cutting off the gas is turned at the commencement of an expiration and air allowed to enter until one full inspiration is completed. The gas is then again admitted and this manœuvre repeated from time to time until a sufficiently deep narcosis is obtained. If too much air is given the anæsthesia will be brief and unsatisfactory. In some cases in which there is an initial cyanotic condition, air must be used more freely or given continuously by allowing the air cut-off valve to remain slightly open.

Various methods have been suggested whereby the patient is given definite quantities of air and gas. That of Mr. Carter Braine ‡ is simple and depends upon having an aperture in the face-piece controlled by a metal cap, the rotation of which admits air to the required amount, but the most exact is carried out by the apparatus shown in fig. 16 (p. 80). The principle involved in Mr. Coleman's § stopcock is that the entry of air and gas is made through apertures of equal size, while the amount of the former

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* Laryngeal stertor must be carefully discriminated from " snoring." Patients with a thick pendulous uvula, or enlarged tonsils or post-nasal adenoids, begin to snore a few seconds after the commencement of inhalation, also persons with loose baggy cheeks make a stertorous sound, but false stertor should be ignored. The true stertor, caused by vibration of the arytæno-epiglottidean folds, only comes on after forty or fifty seconds of inhalation, and is more musical in character.

† The times mentioned are only approximate, as patients differ in their susceptibility to the effects of nitrous oxide.

‡ *Brit. Dent. Ass. Jour.*, April 1895.

§ *Proc. Roy. Soc. Med.*, Sect. Anæsth., Feb. 3, 1911.

admitted depends upon the extent to which the air inlet is opened. The apertures are guarded by a single valve made of aluminium. The inrush of gas lifts this valve and so opens the air aperture simultaneously with the gas aperture ; no air enters, however, unless the air inlet is purposely opened. This is effected by the " see-saw " aluminium plate valve which is in conjunction with the " seats " of the air and gas apertures. Under the movement of
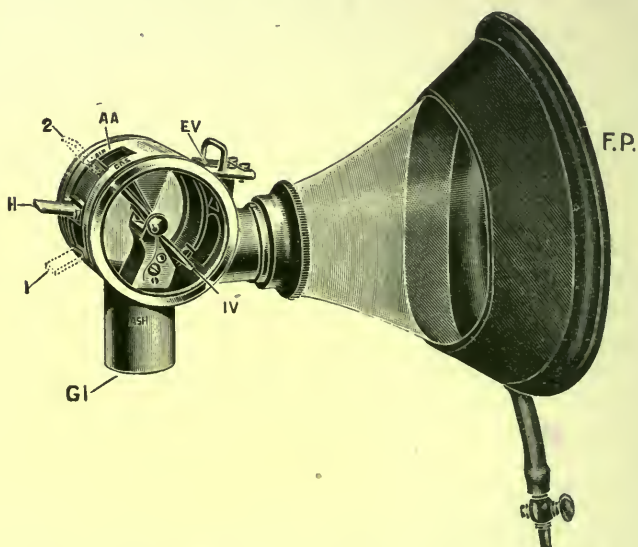

FIG. 16.—Three-way stopcock. (Mr. F. Coleman's principle.)

F P Face-piece, celluloid with detachable rubber rim.
E V Expiratory valve (rubber).
I V Inspiratory valve (aluminium).
A A Air aperture.
G I Gas inlet tube to which the Cattlin's bag is attached.
H   Handle set for nitrous oxide.
1   Handle set for air.
2   Handle set for rebreathing into bag.

the handle H, the aluminium plate valve opens and closes both inlets to the mixing chamber and thus admits air or gas singly or mixed in various proportions according to the position in which the handle is set. To operate the stopcock when administering nitrous oxide, fix the handle H at position 1 for air, and turn it upward to position H for gas. For mixtures of gas and air gradually turn the handle H down towards 1, which will admit the desired amount of air.

The advantage of this method over the one mentioned first is, that it is not necessary to shut off all gas when the admission of air is desired. The actual quantity of air let in will depend upon the requirements of each patient and upon the different periods of the induction, more being needed towards its close than would be necessary near its commencement.

The **signs of unconsciousness** which are most reliable are: the condition of respiration, which becomes automatic in type similar to the breathing during sleep, but more rapid; the expressionless eyes, which usually oscillate slowly; loss of conjunctival reflex, which may occur, but is by no means constant; and fine rhythmic stertor, with vibratory twitching of the orbicularis palpebrarum muscles. Lividity of the face is not constant.

These signs, taken together, form a very definite picture, but experience will soon show the beginner that some of the signs are often difficult to detect and are easily overlooked. The breathing, the colour, and the look in the eyes form, in the absence of stertor and muscular twitching, the best guides. The length of time individuals take to become unconscious varies within wide limits. It is usually about a minute if air is allowed to enter fairly freely, but a longer time may be required. If this time is *much* exceeded and there is no obvious reason for the delay, such as a badly fitting mask allowing in-leakage of air, the tyro should lift the mask and make sure that the patient's colour and breathing are satisfactory. When the anæsthetist is satisfied that full anæsthesia exists he signals to the operator by saying clearly and deliberately, "One—two—three," and then removes the mask, and the operation proceeds. During its continuance he must watch his patient's colour, and prevent foreign bodies—blood, and so on—from interfering with the breathing.

If any tooth falls into the mouth or any complication arises he should stop the operation at once, and take such steps as are called for to prevent danger to the patient. If a patient struggles it is usually better to cease the operation, and postpone it to another occasion, when precautions can be taken to avoid a repetition of the inconvenience.

The signs of recovery.—It is important to be able to recognise the signs of returning consciousness, so as to know when to

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desist from further operative measures, and this can usually be done with certainty. In the first place, the normal colour of the face returns, the lips change from their livid hue to a natural crimson. The eyes recover their look of intelligence. The patient commonly moves a limb, or utters a cry, though not one which implies consciousness; restless movements of the body often occur. Children, also, are very liable to cry out although quite unconscious, and it is well to warn friends of this, otherwise they may imagine the anæsthetic has failed.

It is claimed by some authorities that **rebreathing the gas** towards the end of the inhalation produces a more prolonged period of anæsthesia, and is in no sense prejudicial. To effect this rebreathing, the expiration valve is closed, and the bag becomes a " supplemental bag." It is difficult, even on theoretical grounds, to understand why the rebreathing of nitrous oxide should produce a prolonged effect, even if we admit that the supposed addition of carbon dioxide acts concurrently with the anæsthetic. As has been pointed out, the amount of this gas given off during the inhalation is lessened, so that the quantity acting during the few seconds occupied by the rebreathing would be extremely small. It is the devitalisation of rebreathed air, rather than its impurities, as has been shown by Sir Benjamin Ward Richardson, which renders it deleterious. There is always débris from the lung tissue in rebreathed air, which, in many if not in all cases, it can hardly be desirable to rebreathe. In prolonged administration of this gas with oxygen, some degree of rebreathing is advocated, and the views on acapnia, which are so vigorously advanced by Dr. Yandell Henderson, would appear to indicate that the increase in the tension of carbon dioxide in the blood is by no means harmful. This statement does not, however, in any way invalidate the view the present writer takes that rebreathing, unless for a very short period and after the lungs have been thoroughly washed out with nitrous oxide, is harmful in brief administrations and likely to produce after-headache and malaise.

Occasionally the induction of anæsthesia by nitrous oxide is described in " degrees " of narcosis, but their delimitation is so slight and so empirical that I have not adopted this plan.

The phenomena of the induction of anæsthesia by nitrous oxide varies in different types of persons, and these variations require special lines of management.

CONSIDERATION OF SPECIAL TYPES.

Muscular persons of powerful physique are prone to struggle and fight. They are intolerant of restraint and appear to be peculiarly liable to dreams which excite them to movements while they are only partly " under " gas. They behave somewhat in the manner common in the early days when " nitrous oxide frolics " were in vogue. Too free access of air or oxygen in the early part of the induction increases the likelihood of struggling, while too rigorous exclusion of air (oxygen) in the later part leads to deep cyanosis and violent jactitation during complete anæsthesia. This is due, no doubt, to the hampering of respiration by the tonic contraction of the powerful musculature of the thorax and pectoral girdle. Great care must be taken in the adjustment of the patient's posture, the legs being astraddle on each side of the chair, while free ventilation with pure gas should be permitted at the commencement of the inhalation. Before marked lividity or jactitation occurs, air (oxygen) should be admitted and the depth of inspiration be increased by lifting the mandible upwards and forwards. This will cause elevation of the larynx and so increase inspiratory effort. These patients usually require a considerable quantity of gas and the period of induction is commonly prolonged. Occasionally they become obstreperous as they resume consciousness.

Those of the **alcoholic** type are similar in their behaviour to those mentioned above. They, however, are curiously tolerant of this and all other anæsthetics. They lose consciousness or self-control, but are often difficult to guide into complete motorial quietude, and are prone to resume their semi-conscious violence after an inconveniently brief period of quiet. The anæsthetist has to remember that the confirmed toper is as a rule one whose tissues are fatty and diseased, and so, although it may be necessary to use some air exclusion and to force the anæsthetic, yet a real danger arises if any asphyxial complications are permitted to supervene during the nitrous oxide inhalation. Abstention from food for six hours, from alcohol and tobacco for some days before the administration, with purging, are useful preliminary measures, although the alcoholic are not easily advised in such matters. The blood pressure and condition of the arteries should be investigated in the case of persons over forty years of age. In both the muscular and the alcoholic it is most necessary

to see that the face-mask is fitting with absolute accuracy, as even a little in-leak of air will vitiate the result.

The **feeble, neurasthenic,** and **anæmic** present a problem in contrast to the above. They breathe feebly, are rapidly anæsthetised, but as quickly resume consciousness to pain. They are affected most deleteriously by air exclusion, being liable to syncope and respiratory cessation as well as to unpleasant or even dangerous after effects. The anæmic are peculiarly unfortunate in these respects. Happily, however, with care and judgment, the use of nitrous oxide when given with oxygen or air, the former being preferable, is seldom attended with alarming symptoms in these cases. The guiding principles are a slow induction with free admission of oxygen, the nitrous oxide being more and more diluted until just before the mask is removed, when " charging up " with pure gas is desirable. Personally I refrain from permitting rebreathing in any of these cases, but some authorities advise it. A practical point is to make sure that full lung ventilation is taking place. During the first part of the inhalation these patients will inspire very feebly, and no sufficient tension of nitrous oxide can be achieved. They then doze and the breathing is still more shallow. Unless they are roused and encouraged to inspire, sometimes by pressing upon the jaw or compressing the thorax once or twice, they will hardly become fully anæsthetised. When once the automatic rhythm of respiration is started, this difficulty is at an end ; until then the mere lapse of time must not be accepted as presumptive evidence of the advent of anæsthesia. I have known four minutes to be occupied by a patient before becoming anæsthetised by nitrous oxide when there was no reason save the psycho-physical one for so inordinately prolonged a period of induction. Nervous persons who have had anæsthetics repeatedly and especially if they have suffered " painful experiences," often learn the trick of this ineffective breathing and require special treatment in the manner advised above. However, it is not safe to permit a very prolonged inhalation without watching the breathing closely. If measures to increase lung ventilation fail, the mask should be removed, for in some cases these patients will, by holding their breath, produce semi-asphyxia, and this, with the nitrous oxide taken, may cause grave danger to the circulation and respiration.

Children.—Even infants can take nitrous oxide, but it is not a

good anæsthetic for those under six years of age. Unless a child has been frightened or is unruly through unwise training, it will inhale without trouble. Some nervous little ones become panic-stricken, and for these it is not kind to persist in argument beyond a certain time. If the operation has to be done and the parent recognises that some coercion must be used and agrees to it, it is best to hold the child firmly but gently, and after a few breaths of gas unconsciousness occurs and the child can be placed in the proper position in the chair and the narcosis gradually deepened. Jactitations rapidly occur unless air (oxygen) is admitted ; indeed it is essential to admit it or the period of anæsthesia will be useless for extraction of more than one tooth. Children should always be made to urinate before inhaling, and should not take food for three hours anterior to the operation. They often cry out or sob during the extraction although insentient, and their friends should be warned of this. In very nervous persons and some children, the " open " method (figs. 17 and 18 ; see p. 88) is useful as a commencement of the induction, as the administrator can talk to them as if nothing was going on, and they do not perceive the gas is being taken. I think, as a rule, children should be taken into our confidence and everything explained. They should never be deceived, and no attempt be made to use violence, the object of which they cannot understand and justly resent. The self-willed, spoilt child, however, compels some *force majeure* in his case, but its employment should be explained to him as due to his own recalcitrancy.

Conditions of Respiratory Embarrassment.

The chief causes are—inflammatory swellings of the tonsils, fauces, tongue, and tissues of the neck adjacent to the larynx and trachea (angina Ludovici), contraction of scars after severe burns, glandular or other swellings, including œdema, so situated as to displace or compress the upper air-passages ; adhesions of the palate to the posterior pharyngeal wall, large masses of post-nasal adenoid growths, stenosis or occlusion of the nares ; intrathoracic conditions* due to acute or chronic disease, which

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* In this connexion the persistence of an enlarged thymus gland must be remembered. This is commonly found in those who suffer from lymphatism. Although definite evidence proves that a persistent thymus may press unduly upon the trachea, it does not always do so. Enlargement of the thyroid gland is often associated with a persistent thymus.

either compress the trachea and bronchi or cause fluid to collect in the air-passages ; abdominal enlargement due to fat, fluid, gas, or growths interfering with the diaphragmatic respiratory excursion and incidentally displacing the heart ; general diseases, such as fevers, nephritis, cerebellar disease, bulbar disease, and so on, which either cause dyspnœa or bring about œdema ; pleuritic adhesions are regarded by some as peculiarly dangerous.

In minor degrees of dyspnœa the use of oxygen with nitrous oxide, with sedulous avoidance of any asphyxial condition, may render the use of nitrous oxide fairly safe; but when marked respiratory embarrassment exists, and in all inflammatory swellings involving the trachea, nitrous oxide is contra-indicated.

Circulatory impairment.—The special difficulties and dangers of giving nitrous oxide to patients, who are the subjects of disease affecting the heart or vascular system or nervous mechanism controlling the circulation depend rather upon the results of the pathological condition than upon the lesion itself. The anæmic, the " overgrown " boy, the nervous, sensitive child subject to fainting, persons with hypertrophied hearts, or with high blood pressure associated with markedly rigid arteries, may be classed with " blue " patients whose cyanosis arises from congenital malformation, and constitute the most dangerous types of persons for anæsthesia by nitrous oxide. Syncope, rupture of a cerebral vessel, and asphyxia are the perils threatened in these cases, and if the conditions are at all marked it is probable that some other form of anæsthetic should be adopted. However, provided care is taken to avoid struggling or undue exclusion of air (oxygen) slight degrees of circulatory derangement do not contra-indicate nitrous oxide, they merely serve as indications of particular dangers and suggest the remedies, *i.e.* free admission of oxygen or air and avoidance of all " pushing " of the anæsthetic.

General diseases have been referred to, and it now remains to point out that they only affect the patient through any tendency they may have to cause respiratory or circulatory embarrassment, and their treatment from the point of view of the anæsthetist is that indicated in dealing with these conditions. It is sometimes asked whether the so-called *status lymphaticus* constitutes an especial danger, and the answer is that such a condition, even if accurately diagnosed, is merely one denoting poor development and feebleness, and, although special care to avoid asphyxia and

consequent heart strain is necessary, there is no serious danger in the use of nitrous oxide in these cases.

Menstruation, pregnancy, and lactation.—If it is considered desirable to undertake an operation upon women during these times, nitrous oxide, provided cyanosis and jactitation are completely prevented, may be given. The fœtus may be damaged by prolonged air exclusion, and violent muscular contractions may cause premature birth, but such complications should be prevented by the free admission of oxygen or air.

There will be rather more nervous prostration during lactation than occurs under normal conditions, and the first milk after the operation may be better rejected; otherwise no special anxiety attaches to these cases.

Children possessing small lung ventilation pass rapidly under " gas," and develop early muscular movements and these are often very pronounced. The recovery is equally rapid, so that to secure a maximum period of quietude for operating little air exclusion must be practised. The gas and oxygen mixture is the best anæsthetic to use, and if air and nitrous oxide are relied upon the greatest care must be taken by avoiding air limitation to prevent any suffocation or muscular movements. I have seen more than one cessation of respiration in young children which took place under nitrous oxide, but was at once remedied by gently compressing the chest.

The aged, as a rule, present no special difficulties; they are, however, intolerant of any asphyxial complication, and should such occur there is distinct danger of its causing faintness or even syncope. Air or oxygen should be given freely throughout, and every effort made to prevent the slightest blueness or muscular spasm.

After Effects.

These are, as a rule, conspicuous by their absence; hysterical women may laugh and cry, and work themselves up to a pitch of excitement, which sympathetic friends attribute to " the gas " ; persons exhausted by fasting and vigil or disease may become faint ; epileptics occasionally have a fit during the exhibition of the gas, or immediately afterwards. Vomiting is rare after nitrous oxide gas, although such a complication may occur with children, or if the anæsthetic be given immediately after a meal.

Pereira states that in one case loss of taste followed it, and I have met with a patient by whom anosmia was complained of for some days subsequently to the extraction of a tooth under nitrous oxide. Among a few persons of peculiar organisation, certain nervous symptoms have been known to follow, as for instance, severe headache and general malaise. Sleeplessness for a few nights occasionally occurs ; I have met with it in a young delicate girl, who evinced no other ill-effect after inhaling nitrous oxide. Transient albuminuria has also followed it. It is alleged that glycosuria and even diabetes have been caused by the inhalation of nitrous oxide ; personally, I have never known of any such complications. These symptoms, rare after a single administration, are less infrequent when this anæsthetic has been given twice at one sitting ; hence it is better, when possible, to avoid the repetition. There is no doubt, I think, that patients who for some reason have become cyanosed, and whose respiration has become unduly laboured under the anæsthetic, are much more liable to these minor after effects than is the case with a normal uncomplicated administration. The graver dangers and deaths which have occurred under this anæsthetic are considered below (pp. 97, 121, *et seq.*).

Open method. — Certain persons and children are greatly alarmed by having a face-piece held over their nose and mouth. To obviate the necessity for this Dr. Flux has devised an ingenious plan for giving nitrous oxide by an open inhaler.* His procedure is as follows :—Gas is poured into the upper open part of the inhaler through the stopcock leading from a gas-bag connected in the usual manner to the source of supply. The nitrous oxide gas is only allowed to flow during inspiration, and owing to its greater weight falls directly into the face-piece. The movements of respiration, and the warmth of the expired vapour, tend to empty the inhaler, to prevent stagnation of its contents, and to favour the mixing of gas with air. Violent injection of the gas into the face-piece is undesirable, especially in the case of small persons or shallow breathers, as the air by these means may be completely driven out before diffusion of the gas has had time to occur.

The inhaler is open at the top, and the edges must fit the face accurately in order to prevent any escape of gas below

* See Dr. Flux's paper in *Transactions of the Society of Anæsthetists,* vol. ii. p. 140.

the level of the nose and mouth. With very young children
it is often convenient to use simply a folded napkin instead of
a formal face-piece. In other cases, where it is inconvenient to
employ a specially constructed open inhaler, an ordinary face-
piece kept open by being tilted back from the face can be used.
I have frequently adopted Dr. Flux's plan, and although recognis-
ing its merits in simple cases, I think it is better, when employing
this method, to commence the inhalation by the open inhaler
and conclude with the usual closed mask. In this way one avoids

FIG. 17.—Flux's open method. Patient in recumbent position.

the initial fright and yet ensures a deeper narcosis and better
anæsthesia than can be relied upon when the open mask is used
throughout the administration.

PROLONGED ADMINISTRATION OF NITROUS OXIDE.

For cases where the operator requires an appreciably longer
period for his work one or other of the following methods may
be employed.

By mouth-tube.—Mr. S. A. Coxon's method * is as follows :—
The patient is rendered unconscious by the use of the usual
apparatus. The face-piece is then removed and a bent tube of

* *Transactions of the Society of Anæsthetists,* vol. i. p. 123.

large calibre connected with the nitrous oxide supply is introduced
into the mouth so that its free end is a short distance from the
uvula.   It is most conveniently passed behind the dental prop.
A steady stream of nitrous oxide, which Mr. Coxon recommends
should be warmed, is maintained until the operation is completed.
Unless this warming is efficiently carried out the gas produces
such cooling of the fauces as to cause undesirable results.   The
method has now been superseded by nasal methods.

FIG. 18.—Flux's open method.   Patient in sitting posture.

Administration by nasal methods.—The use of nasal tubes
and catheters for maintaining nitrous oxide anæsthesia was
suggested by the late Mr. Alfred Coleman, who wrote to me
about his plan many years ago and subsequently made a
simple apparatus * which I used for a time at the Dental (now
Royal Dental) Hospital of London.   Mr. Harvey Hilliard † has
suggested an apparatus which in his hands appears to be successful.
The plan consists in introducing a catheter through the nostril
so that its free end hangs over the opening in the larynx.   The
nitrous oxide, as soon as anæsthesia has been induced by ordinary
methods, is diverted and enters the air-passages through the
catheter.

* Subsequently described in 1898 before the Society of Anæsthetists ; see
Transactions, vol. i. p. 117.
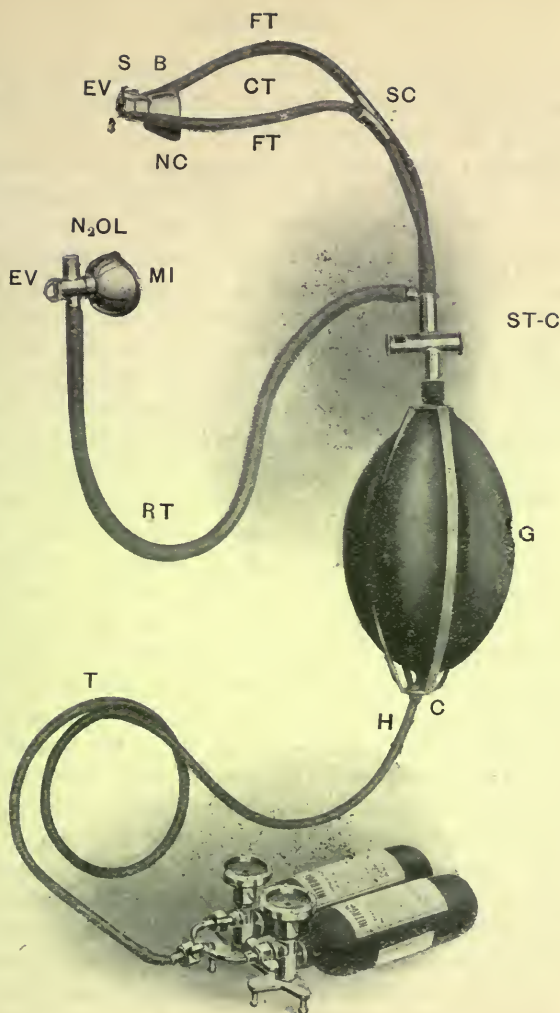† *Op. cit.*, vol. i. p. 170.   See also *Dental Record*, April 1, 1898, p. 147.

FIG. 19.—Mr. F. Coleman's combined mouth and nose nitrous oxide inhaler.

Combined mouth cover and inhaler—

MI—Mouth cover.	EV—Expiratory valve.
N₂OL—Nitrous oxide lever.	RT—Rubber tubing.

Nose-piece, etc.—

EV—Expiratory valve.	SC—Sliding clamp.
B—Body.	ST-C—Stopcock.
S—Shutter.	G—Gas-bag distended.
CT—Conveying tubes.	C—Gas-bag compressor distended.
NC—Nose-cap.	H—Tubing to gas-stand.
FT—Flexible tubes.	

Mr. Alfred Coleman's original plan of giving nitrous oxide by the use of a nasal cap has been improved by his son, Mr. Frank Coleman, by Mr. Trewby, and others.

In **Coleman's apparatus** (see fig. 19) the cylinders of gas are connected by tubing (RT) with a rubber bag (G) compressed by metal ribs (C). The upper exit of the bag is attached to a stop-cock valve (ST-C) which allows nitrous oxide or air or a mixture of these gases to pass onward to the patient. The nose-cap (NC) is made entirely of metal and is not easily displaced even when upper teeth are being extracted. It is provided with an expiratory valve (EV) and is fitted with lateral tubes of stout rubber (FT) which pass to the back of the patient's head and are held together by a sliding clamp (SC) which keeps the nose-piece in accurate apposition with the face without undue pressure. These tubes then pass down to the stopcock valve, completing the clear way from the gas supply to the patient. In some apparatus the mouth is covered by a metal mouth-cap (MI) provided with an expiratory valve (EV) and the patient is in-structed to inspire through his nose and expire through his mouth. Mr. Coleman has improved this by carrying a second gas-tube (RT) from the stopcock to the mouth-cap so that by depressing the metal handle (N₂OL) the gas enters by way both of the mouth and nose. When this is used it is immaterial whether the patient breathes by his mouth or by his nose. If the handle is allowed to escape, a spring causes it to rise and to close the gas supply to the mouth-cover so that in that case the mouth-cap acts merely as a means of expiration. The weight of the apparatus is supported by a chain and hook which can be attached to the operating-chair. When anæsthesia has been obtained the mouth-cap and tube are dropped and the gas supply maintained through the nose. It is essential that the patient should have a fairly patent nasal passage and this fact should be ascertained before the inhalation is commenced. If there is much mucus in the naso-pharynx the patient should gargle freely with some mild astringent, Tinct. calendulæ and water, or Condy's Fluid, a few drops being poured into tepid water flavoured with a little eau-de-Cologne.

The method.—The prop is fixed in position and the nose-cap is then carefully adjusted while the patient is instructed how to breathe.

Then the mouth-cap is put over the mouth, care being taken

PLATE III.

Shows Mr. Coleman's combined mouth and nasal administration of nitrous oxide. The administrator would usually stand to the left of the chair and the bag would hang behind it. Note method of holding the inhaler and arrangement of tubes and clamp.

that no air can enter between it and the sagging cheeks or below the nasal cap. If the expiratory valve responds well to the patient's breathing the stopcock is arranged so that gas enters both by the mouth and nose. The lever (N_2OL) is depressed to admit gas to the face-piece. The gas supply to mask and nasal cap is controlled by the sliding valve (ST-C). The clamp (SC) slides along the tubes and fixes them in position as is seen in Plate III. If the expiratory valve does not act well the patient
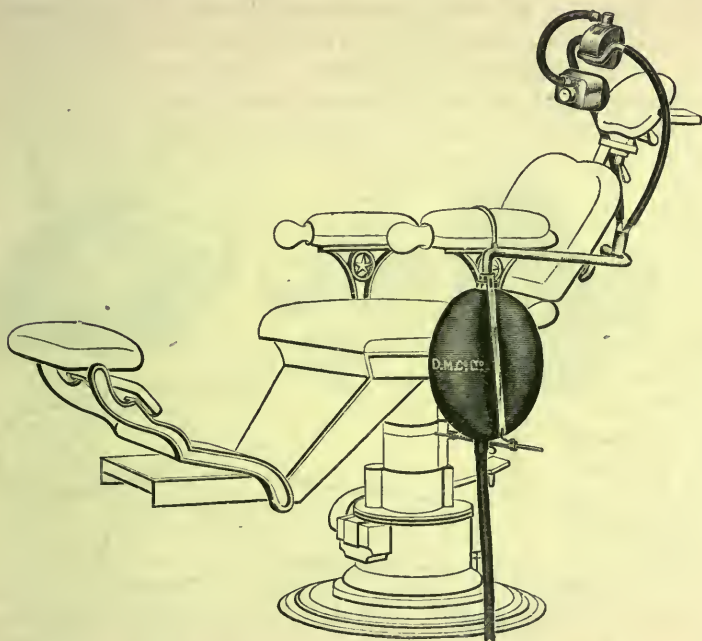

FIG. 20.—Mr. Trewby's nitrous oxide oro-nasal inhaler

must be encouraged to "blow out hard," when the valve will evidence the success of his effort. The signs of anæsthesia are those mentioned in the preceding sections. Its onset is about as rapid as by ordinary oro-nasal methods. There is, however, a greater liability to the supervention of cyanosis and this must be obviated by moving the stopcock so as to admit air or by opening the expiratory valve in the nasal cap.

Provided that the patient breathes well it is possible to maintain anæsthesia sufficiently long for the performance of any dental operations. If the narcosis becomes too light and movement

occurs, the mouth-cap is reapplied, after sponging out any blood which is in the mouth, and the patient is put more deeply under the influence of the gas. Great care must be taken to avoid cyanosis. The recovery is less rapid than in the case of ordinary methods, and the patient is apt to be dazed and sometimes complains of being " done up " after a prolonged inhalation.

Mr. Trewby's apparatus * is somewhat upon the same lines, but possesses many features of excellence which commend it. The figure (fig. 20) depicts its salient points so that detailed description is unnecessary. The method of use is the same as that of Mr. Coleman's apparatus.

A considerable supply of nitrous oxide must be at hand,
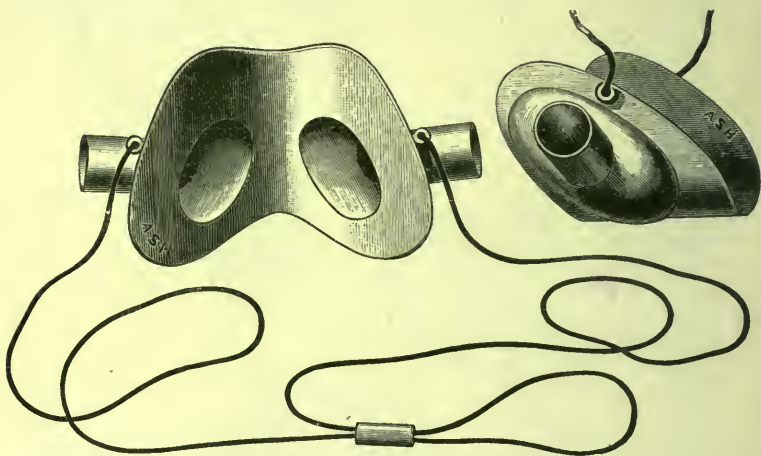

FIG. 21.—Inside and outside views of Mr. Lennox's nasal anæsthetiser.

as 50 to 80 gallons may be required for ten minutes' anæsthesia, although experience with the use of the method enables an administrator to lessen very considerably the amount of anæsthetic expended for each patient.

Mr. Lennox of Cambridge has suggested a very simple and efficient apparatus for nasal anæsthetisation (fig. 21).

Experience has convinced me and others that valuable as are nasal methods, yet they are not so safe as oral methods and should only be employed in selected cases and for patients whose physical condition seems such as to render the strain imposed

* See *Proc. Roy. Soc. Med.*, 1911, vol. iv. pt. i. p. 12.

upon both the heart and the respiratory system a matter of no serious risk to them.

DIFFICULTIES AND MINOR COMPLICATIONS UNDER NITROUS OXIDE.

Retching and vomiting.—Some persons retch as soon as the mouth is fixed open by the dental prop, and actual vomiting may ensue. In most cases this arises from the mouth having been too widely opened and can be corrected by bringing the prop forward and letting the mouth be partially closed. It is occasionally necessary to employ an extremely small prop and open the mouth by means of a gag when the patient is unconscious. In extreme cases, if the patient gargles the throat, or has it lightly sprayed with a solution of cocaine (2%), the trouble can be overcome.

Vomiting is especially liable to occur if the patient is permitted to swallow blood and mucus, so that, when multiple operations are done, a sponge secured by a string should be placed over the oozing sockets as soon as the extractions are completed.

More troublesome patients are those who commence to retch at a point when unconsciousness has occurred but the narcosis is only light. It is usually impossible to push the nitrous oxide inhalation, and one has to be content with a brief anæsthesia, or adopt another anæsthetic. I have more than once met with patients, dyspeptics, who " belch " as soon as the prop is applied and then retch and complain of great distress. It is necessary in extreme cases to give gas, either nasally without a dental prop, inserting one when the patient is unconscious, or to anæsthetise, insert a prop, and then re-anæsthetise. Probably the former method is the better one.

Holding the breath by nervous patients can usually be overcome by the anæsthetist's tact and a few encouraging words, but I have met with persons who have induced semi-asphyxia and faintness by their persistence in breath-holding. Pushing the jaw forward rhythmically will induce an inspiration, and breathing once started will be maintained. Force should never be used except when it is necessary to prevent the patient from hurting himself. Children may be restrained, however, and compelled to inhale provided their parents are willing that a certain amount of firmness should be employed. In every case of breath-holding it is essential that one should ascertain whether

any physical reason for it exists, such as spasm of the larynx
or faulty position of the patient.

Coughing, sneezing, and " gagging " seldom give trouble
except in the stout and plethoric. If there is reason to fear
the result of straining, as when the heart is feeble, it is better to
give oxygen freely, or, failing this, air, and not to press the an-
æsthetic until the complication has passed off. If the condition
occurs early and obviously produces great distress, it is better
to take off the face-piece and start *de novo* when the patient has
got over the attack. " Gagging " is usually due to irritability
of the pharyngeal wall and commonly occurs in smokers. In
slight degrees it is remedied by pushing the anæsthetic. If the
condition is known to be present a preliminary gargle and spray-
ing of the throat with 2% cocaine solution are useful.

Pallor and cyanosis.—Paling in young patients may arise from
slight faintness, but must be closely watched, as, if it increases,
especially when nitrous oxide is being given by itself, it may
lead to syncope and require prompt treatment, such as lowering
the head or semi-inversion. Cyanosis, on the other hand, is
commonly met with among elderly persons, especially if stout
and plethoric. It increases even after the withdrawal of the face-
piece, and requires careful treatment. Even with oxygen this
condition may supervene, and if in spite of increasing the oxygen
it is not removed, the patient should be allowed to come round,
as forcing nitrous oxide in these cases is a dangerous practice.

Hæmatemesis and epistaxis.—The former rarely occurs,
and when it does must be treated on general medical principles.
It is obviously essential to place the patient in a recumbent
posture and to turn the head to one side. But, like epistaxis,
a minor degree of hæmatemesis may occur, and not be recognised
if the administrator has allowed his attention to flag. Epistaxis
will seriously interfere with respiration when the head is extended.
Slight nose bleeding is not at all uncommon after inhaling nitrous
oxide ; it is most common among young persons. In either
case, the administration must be stopped as there is danger of
blood trickling into the air-passages or clotting over the rima
glottidis, thus interfering with respiration.

Hæmoptysis.—In cases of phthisis bleeding from the lungs
may, but seldom does, occur during the administration of
nitrous oxide. I have never seen a case of such a hæmorrhage,
but cases of it have been recorded.

Hysteria and excitement.—Occasionally excitement, almost maniacal, occurs after nitrous oxide, while lesser degrees of emotional disturbance are not uncommon. No serious treatment is necessary; judgment and firmness will meet the requirements of the case. The tendency to erotic dreams and hallucinations under these circumstances should be remembered and steps taken to prevent displacement of clothing and sliding of the body out of the chair. The liability in the case of women to believe they have been indecently assaulted while unconscious enforces the necessity of avoiding being left alone with a patient under such circumstances.

Dislocation of the jaw, either partial or complete, may occur. The relative position of the teeth in the maxilla and mandible should be noticed as soon as the dental prop is removed, and if the jaws cannot be closed prompt measures must be adopted to reduce the subluxation, if possible before the patient is fully conscious. Patients often volunteer the statement that their jaws " are very loose, and slip out," and this warning should cause care to be taken to support the mandible and to avoid an unduly wide separation of the jaws by the dental prop or gag. The treatment is usually simple. Standing in front of the patient, the surgeon protects his thumbs with two cloths wrapped round them. He places his thumbs as far back as possible on each side in the molar regions, and exercises steady but firm pressure downwards and backwards, while, with his fingers grasping the mandible, he lifts this up and so slides the displaced condyles back into their sockets. In returning, the muscles snap the jaws together, and unless the thumbs are properly protected they will be severely bitten. Incomplete dislocation is the commoner accident and is generally reduced with ease. Bruising of the tongue, lips, or gums with forceps or gags, or burning with carbolic acid, can only result from carelessness, but their possibility should be kept in mind. The same applies to breaking or displacing teeth when introducing a gag. Usually if the tooth is replaced in its socket it will eventually get firm.

DANGERS ATTENDING NITROUS OXIDE ADMINISTRATION.

Respiratory difficulties.—In some cases, a certain amount of **laryngeal spasm** may occur, although it is rare. A case has been reported in which this condition was so severe as to

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render laryngotomy necessary.* As a rule, drawing forward the tongue, using rhythmic traction, will relax the spasm. Breathing in some cases becomes very shallow and may stop altogether, but this need not cause alarm, unless indeed it should cease for longer than a few seconds. Then it is well, after seeing that there is no falling back of the tongue or foreign body impeding respiration, to press up the ribs from below by standing in front of the patient, and grasping the chest with both hands placed about the lower half of the bony thorax. This simple manœuvre will initiate spontaneous respirations, and all will go well. Young children occasionally cease to breathe if the nitrous oxide is pushed to profound narcosis, and compression of the chest becomes necessary. Patients suffering from conditions such as inflammatory swelling of the neck, laryngeal stenosis, goitre, or enlarged glands, are peculiarly liable to respiratory difficulty under nitrous oxide. As has been pointed out, it is better to avoid this anæsthetic for such cases, and if it is used at all it must be limited in dose, and all asphyxial phenomena carefully watched for and remedied by the use of oxygen, and the upper air-passages must be opened if death from asphyxia is imminent. Even enlarged tonsils, especially when inflamed, may cause serious danger under this anæsthetic. A case in which death followed the administration has been recorded † (see p. 121, Case I.). I have on a few occasions met with respiratory difficulty, which was fortunately only transient, evinced by cyanosis and severe dyspnœa in persons whose only apparent

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* This instructive case was published by Sir F. Hewitt. A patient, æt. 35, suffered from fixation of the bodies of the vertebræ which precluded all save very slight rotatory and nutatory movements. The neck muscles were unduly rigid and the jaws could be opened only to a fourth of the normal extent. The fixation was the result of rheumatic fever. The gas was taken well and the tooth extracted. It was then remarked that the usual recovery did not occur, the respiration becoming more and more embarrassed, " as though some obstructive condition of the air-passages " existed. " The sound made by the last attempt at respiration was to a certain extent suggestive of fluid at the back of the throat." General fixation of the thoracic walls and rigidity of the jaws and vertebræ as well as of muscles of the neck rendered the measures usually adopted, such as artificial respiration, swabbing out the pharynx, etc., impossible ; and, as inversion failed to restore the patient's respiration, Sir F. Hewitt performed laryngotomy, which at once relieved the spasm, and the patient did well. See " Anæsthetics," 4th ed., 1912, pp. 564-5.

† *Transactions of the Society of Anæsthetists*, vol. vi. p. 12.

disability consisted in their being plethoric, and having a short thick neck and rigid chest.

Asphyxia caused by foreign bodies.—Vomiting during inhalation of nitrous oxide is uncommon, but may occur and even escape notice. If the vomit is aspirated into the lungs fatal results may follow, especially if the patient has incautiously taken solid food recently. Bleeding from the nose, throat, stomach, or lungs, or bursting of an abscess in the tonsil or pharyngeal wall may cause suffocation, as they are easily overlooked.. Portions of undigested meat or other solid food may, of course, become impacted in the glottis and cause dangerous or fatal results. Impaction of masses in the œsophagus may produce suffocation by pressure. A sponge used to prevent blood entering the larynx has in one case proved fatal. The person who placed the sponge in position appears to have forgotten it, and it was allowed to remain over the glottis, occluding the air-passage while artificial respiration was kept up. Among dangers must be mentioned those which are due to the operation rather than to the anæsthetic. Thus, a prop placed between the teeth may slip back into the windpipe, if not secured to another prop hanging freely outside the mouth. Accidents have arisen through breaking of corks or dental props, so that the latter should be made of some material not liable to crack or break off. The mouth must be cleared of artificial dentures, especially small plates. Accidents have occurred from teeth or portions of teeth being allowed to fall back from the beaks of forceps to the glottis, and thence entering the trachea. Premolar teeth, from their shape. are very prone to jump out of the forceps during extraction (Case B, p. 125). In several recorded cases these teeth have entered the trachea and caused death, either at once, or secondarily by causing abscess of the lung. The tooth forceps themselves have broken, and a fragment become lodged in the bifurcation of the trachea.

The dangers of these casualties are :—(1) immediate, from asphyxia due to laryngeal spasm excited by the foreign body becoming impacted in the larynx ; and (2) secondarily from septic pneumonia set up by the foreign body having found ts way into a bronchus.

To deal with such cases.—Firstly, as to precautions. All instruments used for the mouth should be carefully examined for flaws, and all gags, props, etc., secured by fishing-gut, or some strong, cleanly material, and attached outside the mouth.

In extracting teeth the forceps should, after each extraction, be wiped quickly *twice* across a napkin, in order to free them from the tooth just removed before the next extraction is attempted. Fragments of teeth should never be left loose in the mouth, even with the object of gaining time. The use of the mouth-spoon (p. 74) will often avoid these serious accidents.

Should there be any fragments detached from the tooth or forceps, etc., which cannot be seen and picked out, the anæsthetist should at once bend the head forward and sweep the finger round the mouth so as to carry any foreign body forward, where it can be seized and removed; in this way it may sometimes be possible to dislodge a foreign body lying near to the epiglottis. It should be remembered that the tongue must **not** be drawn forward, as by doing this the larynx will be left exposed, the epiglottis being dragged from it; also because the patient is thereby induced to take a deep inspiration which facilitates the passage of the foreign body into the air-passages.

If the obstruction cannot be felt, and there are signs of impending asphyxia, inversion should be attempted, and the patient, if sufficiently conscious, should be instructed to breathe out very deeply, coughing with the act, while he inspires as shallowly as he can. This manœuvre has succeeded in dislodging a tooth which had passed into the trachea. There is, however, a danger that inversion may cause the foreign body to lodge in the larynx and so excite spasm, and should this occur the trachea must be at once opened.

Failing all other measures, if the patient be dyspnœic and death by asphyxia seems imminent the trachea must be opened by tracheotomy * (see Chapter X.). If the symptoms are not too urgent it is wise to postpone operation and seek the aid of a skilled laryngologist, who, by the use of the bronchoscope, may obviate a cutting operation by picking out the foreign body from the bronchus. When the asphyxial symptoms are due to the patient having vomited into the face-piece, it will usually suffice to open the mouth, if not already open, and sponge away the vomitus or other fluids. However, solid food may become impacted in the rima or œsophagus occluding the larynx by pressure, and so necessitate the opening of the trachea below the obstruction.

* The operation of laryngotomy, which some authorities recommend in these cases, is less effectual.

Syncope.—Among the graver complications may be noted syncope. While syncope seldom occurs during nitrous oxide narcosis, it is undoubtedly a possible danger, especially among the neurasthenic and feeble, and in the case of elderly people who are fatigued by unwonted exercise such as coming upstairs rapidly. It may take place before the onset of complete narcosis, and then is probably due in part to subjective sensations, such as dread of the impending operation, terror of the anæsthetic, or fear of suffocation. There are reported cases in which syncope has only been observed after removal of the face-piece, while in others all has apparently gone well until the operation has been commenced, when the condition of the patient suddenly became alarming. Whether death from syncope due wholly to nitrous oxide used in minor operations has ever occurred is doubtful. In the few deaths which have attended the use of nitrous oxide, and have been reported, incomplete anæsthesia has played an important part, while fright and shock have undoubtedly contributed to the causation of the fatal result. When this anæsthetic is given without regard to the avoidance of asphyxial complications it may lead to syncope, due to grave interference with the pulmonary circulation. Persons whose breathing is hampered at the time of taking nitrous oxide incur the gravest danger of syncope, if this gas is incautiously employed. The anæmic are also liable to this danger, unless care is taken to avoid undue deprivation of oxygen. Stout women wearing tightly laced corsets are prone to syncope, and have succumbed to this while under the influence of nitrous oxide, especially when the stomach was distended by a recent meal.

Faintness. — Less severe forms of circulatory failure may, however, sometimes supervene, such as faintness, and these should be counteracted by placing the patient supine on the ground, chafing the hands, applying smelling salts or aromatic vinegar to the nostrils, and slapping the face and chest with towels wrung out in very cold water. All garments about the waist, chest, and neck must be loosened, if this has not been done, as it should have been, before the gas was administered. The inhalation of a few whiffs of nitrite of amyl will often relieve the heart. It is sometimes advised to inject ether under the skin, but the utility of this is doubtful, nor is it likely to be called for in the class of cases above mentioned. A measure which I have practically tested and have every reason to estimate

very highly is partial or total inversion of the patient. In the movable dental chairs so commonly used, this can be done even in the case of women, without indelicacy or difficulty. In minor degrees of faintness such as often supervene after an extraction, bending the body down so that the face is placed between the patient's knees will expedite recovery. A few inhalations of oxygen will often greatly assist such persons and raise blood pressure. Such transient faintness is commonly the result of nausea, or may even herald vomiting. It must always be borne in mind, when giving nitrous oxide to a stranger, that he may be the subject of cardiac disease or angina pectoris and may not associate any danger with this condition even if he knows of its existence. Some slight emotional disturbance, fatigue or oppression due to a walk in sultry weather is enough, when added to some respiratory embarrassment due to the anæsthetic, to precipitate serious or even fatal consequences (see Case VI., p. 123).

Mania is a rare complication following nitrous oxide inhalation, which has occurred in persons subject to mental disease.

Epileptic fits may occur during the induction or following anæsthesia, but beyond taking care that the tongue is not bitten, and the air-way is patent, no special treatment is necessary.

Hemiplegia and apoplectic seizures have been recorded as occurring after nitrous oxide, but are extremely rare (see Case A, p. 125). When there have been much straining and cyanosis, ocular ecchymosis and even retinal hæmorrhage may result after this anæsthetic.

The Use of Nitrous Oxide in the Puerperium and in Disease.

Pregnant women, provided they be not within a very short period of their accouchement, are not prejudicially affected by this anæsthetic. The shock of even a minor operation is quite as likely to provoke premature delivery as taking nitrous oxide. The child appears also to be quite unaffected, as one would expect, since its oxygen tension is habitually low, and further because the elimination of nitrous oxide from the blood is very rapid. Especial care should be taken in administering nitrous oxide in these cases, and all asphyxial complications must be avoided, as the nervous system is peculiarly liable under such

conditions to receive strong impressions and is easily thrown off its balance. Hysterical emotional outbursts if they occur will certainly be attributed to the inhalation, so that, unless imperatively called for, operative measures should be deferred until after parturition. In the early months of pregnancy vomiting may be excited by nitrous oxide.

Lactation is not in the majority of cases prejudicially affected by nitrous oxide gas. **During menstruation** women may safely take this anæsthetic, with the reservation that since the nervous system is at this time less stable than usual, these patients will be rather more likely to be " upset," hysterical, and so on. It is noticed elsewhere that erotic hallucinations under nitrous oxide are more prone to occur at the " monthly period " than at other times.

Advanced age, as such, offers no reason for declining to administer nitrous oxide, patients over ninety having taken it successfully. When great **vascular feebleness** exists, there is more risk, as the greater tax imposed upon the heart by checking oxidation in the lungs, and so impoverishing the tissues, may provoke syncope. However, with due care and watchfulness, even the very feeblest can take nitrous oxide with impunity. In practice I have found it wise to administer a little ether in conjunction with the gas when great circulatory enfeeblement is present.

In extensive lung disease, especially in phthisis, when hæmorrhage has been known to have occurred, nitrous oxide must be given with caution, as there is danger of exciting fresh bleeding from the lungs.

Heart disease, except when the tendency to syncope is considerably increased, is no contra-indication to giving nitrous oxide. In all cases it is necessary to weigh in one's mind which will be more likely to jeopardise the patient's welfare—the performance of an operation without an anæsthetic, or the giving of the anæsthetic. Broadly it may be stated that if the patient can support the shock of the operation, he will certainly survive the anæsthetic. The alternative plan, namely, the adoption of regional or local analgesia must be considered in such cases; but nervous persons are not, as a rule, good subjects for local treatment of this kind, as fear-shock is not abrogated by it and such shock is dangerous in these cases. **Valvular disease,** unless marked want of compensation is present, is not contra-indicatory

to nitrous oxide inhalation. When the heart is greatly **dilated** and the **hypertrophy** has failed to overcome the obstructed circulation, or when marked muscular degeneration of the heart fibres has taken place, there is necessity for caution, and of such patients the most anxious care should be taken. In all the cases referred to in this section it is best to employ nitrous oxide and oxygen, or air, rather than to rely upon nitrous oxide by itself. Excessive **blood pressure** is a serious danger since nitrous oxide itself provokes increased arterial pressure, and if any asphyxial complications are allowed to intrude the blood pressure will be still further increased and the danger of a hæmorrhage due to rupture of an artery in the brain is then considerable. Hemiplegia has been reported in several cases as a sequela of nitrous oxide. Gas and oxygen is safer in such cases, although even this mixture is not free from danger.

DEATHS FROM NITROUS OXIDE ADMINISTRATION.

Several deaths have been imputed to the use of this agent, but it is doubtful whether any of the fatalities during brief administration recorded were due to the physiological action of nitrous oxide gas. In some instances insufficient narcosis was maintained, and as a result the patient *felt the pain*, and syncope ensued. In others, either the entire gag or a portion of it slipped, and found its way into the patient's larynx, there to excite spasm and cause suffocation. A fuller account of these fatalities will be given at the end of this chapter.

NITROUS OXIDE GAS WITH OXYGEN.

The apparatus devised by M. Fontaine for carrying out Paul Bert's method of giving these gases under pressure, has practically gone out of use, so a mere mention of it will suffice. The name of Paul Bert must, however, always be remembered with honour in this connexion for his classical researches (*Compt. rend. de l'Acad. des Sc.*, 1878, 1879, etc.) which paved the way for the present simpler and better methods.

Dr. Hillischer was one of the first to point out the value of associating oxygen with nitrous oxide. He called the mixture *schlafgas*, and in a pamphlet under this caption advanced his reasons for its use and described his apparatus contrived for their exhibition.

This apparatus I have used, but have not found it so satisfactory as more recent inventions. The inhaler devised by Sir Frederic Hewitt is described below.*

The apparatus.—Two bags completely separated by an india-rubber division contain the two gases. The employment of separate bags has one advantage, viz. that if one bag is distended it does not exert pressure upon the second bag and so defeat the object the administrator may have in view, that namely of producing a plus pressure of one or the other gases which he is employing. These are severally connected by tubes, arranged one within the other, with the steel cylinders containing the oxygen and nitrous oxide respectively. The oxygen passes into a small chamber which is separated from the mixing chamber, but can escape into the latter by one or more perforations in the wall when the revolving inner drum is turned. This is moved by a handle attached to the indicator. The figure given below shows the apparatus complete (fig. 22), and the various portions of the regulating stopcock with the mixing chamber are seen in fig. 23, p. 107. Fig. 23 shows in detail the arrangement of the mixing chamber and the working of the various valves. As success in the use of this apparatus depends upon these being in order, it is wise for the anæsthetist to separate the parts periodically and inspect the condition of the valves, so as to see whether they are in their correct position, and whether the rubber of which they are composed has perished and needs renewal. If this is not done the gases may pass back into the bags and become mixed, and if a valve only sticks, the supply may be cut off and failure ensue, causing distress to the patient and chagrin to the anæsthetist. A supplementary stopcock can be fitted which enables the administrator to increase the supply of oxygen to meet any emergency.

The most careful attention to carrying out its details is essential for this method. The utmost accuracy in fitting the mask, and excluding the entrance of air beneath the air-cushion are essential. It is well also to make oneself quite sure that the terminals, *i.e.* the N_2O and O_2, are attached to the appropriate bags. The metal collars should have the above letters impressed or scratched upon them to avoid possible mistakes.

* The figures of his apparatus were lent to me by the late Sir F. Hewitt and appear in his book, " The Administration of Nitrous Oxide and Oxygen for Dental Operations," Claudius Ash and Sons, London.

The patient should be made to breathe two or three times through the apparatus (fig. 22) to ascertain that the valves are working, or, better, the anæsthetist should himself test them
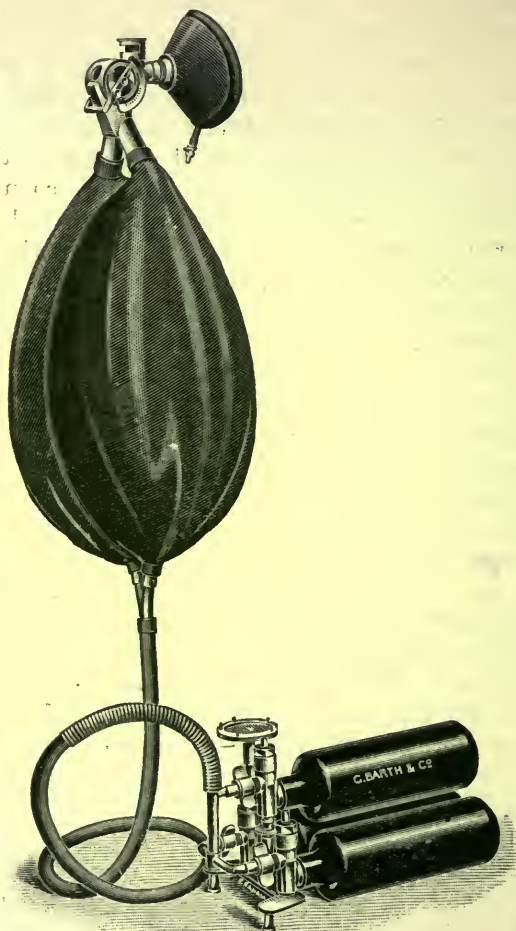

FIG. 22.—Apparatus for giving nitrous oxide gas with oxygen.
(Sir F. Hewitt.)

before applying the mask. The handle attached to the indicator is then to be turned so that the latter points to "2," thus permitting a small quantity of oxygen to mix with the nitrous oxide. If the patient is a child, is anæmic, or shows signs of

rapidly developing cyanosis it is well to push the indicator at once to " 4." After a few breaths, if any duskiness appears, the indicator may be pushed to " 5 " and " 6 " or onward as the judgment of the administrator suggests. The appearance of signs of cyanosis, stertor, muscular twitchings, are indications
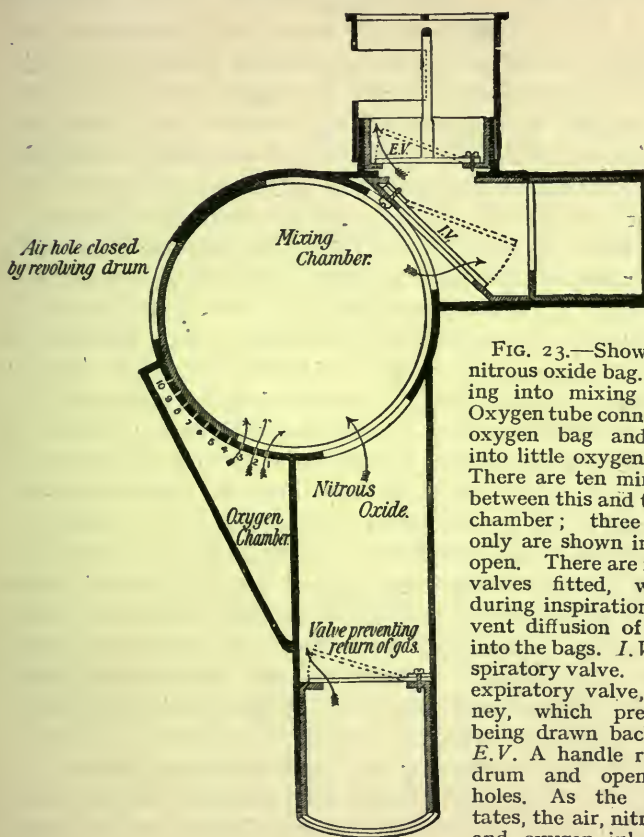
FIG. 23.—Shows tube to nitrous oxide bag. Its opening into mixing chamber. Oxygen tube connected with oxygen bag and opening into little oxygen chamber. There are ten minute holes between this and the mixing chamber; three of these only are shown in figure as open. There are removable valves fitted, which act during inspiration and prevent diffusion of the gases into the bags. *I.V.* Main inspiratory valve. *E.V.* The expiratory valve, its chimney, which prevents air being drawn back through *E.V.* A handle rotates the drum and opens oxygen holes. As the drum rotates, the air, nitrous oxide, and oxygen inlets are respectively opened and closed. The drum is not shown in the figure.

for allowing more and more oxygen to enter the mixing chamber, while the presence of a ruddy red flush over the forehead, an apnœic condition without blueness, the commencement of purposeful muscular movements, signs of excitement, talking, persistent consciousness, are indications that the patient is

getting too much oxygen. In this case the indicator can be
turned back to " 2 " or even " N₂O " until quietude is established.
At this stage it is well to again allow some oxygen to enter,
and, if the patient takes this percentage with success, to allow
him to inhale for a minute or so after anæsthesia has developed
itself. In this way a more prolonged period of anæsthesia is
obtained. This will be necessary when the apparatus is used
for prolonged anæsthesia. The bags should be only partly dis-
tended and maintained as nearly as possible of the same size
throughout the administration. If, however, the symptoms
are carefully watched I think perhaps the best results are obtained
by keeping the oxygen bag about half full, and varying the fulness
of the nitrous oxide bag as the symptoms seem to demand. It
must, however, be remembered that filling the one bag exerts
pressure upon its companion through the dividing septum, and
hence neither bag should ever be filled to more than two-thirds
of its capacity. The possibility of a small opening between the
bags should be borne in mind if anomalous symptoms caused
by an excess of oxygen in the mixture become apparent. At
the point when the patient is anæsthetised it is my custom to
discontinue the supply of nitrous oxide or oxygen from the
cylinders and to allow the patient to breathe the mixed gases
without any added pressure from the inrush of a fresh supply.

A somewhat similar inhaler has been devised by Mr. Wellings.
It possesses an advantage over the one just described in that
the supply of oxygen is regulated by wedge-shaped slots such
as are used in carburetters instead of by a series of round
apertures. This provides a more even and reliable flow of the
gases and is more easily cleansed. I have used this inhaler
and find it most satisfactory.

The inhalation will occupy in many cases two minutes or
even longer.* Indeed, the longer the period of induction is,
provided too much oxygen has not been admitted, the more
satisfactory will be the anæsthesia. The **signs of anæsthesia**
are soft " distant " snoring breathing, fixation of the ocular
globes, and usually an insensitive conjunctiva. The muscular
system should be fully relaxed. The pupils usually remain of
normal size. The **period of anæsthesia** varies within wide
limits, but is usually slightly longer than when nitrous oxide
is given alone. **After effects** such as **languor, nausea, vomiting,**

_____

* Sir F. Hewitt gives his average as 110 seconds.

headache, slight vertigo, which follow the use of nitrous oxide diluted with oxygen, are slightly more frequent than is the case when nitrous oxide is used alone. This is probably due in part or entirely to the more prolonged period of the induction of anæsthesia. The patients are longer in recovering their wits and occasionally remain in a dazed state for some minutes. The **after effects** following the use of nitrous oxide and air are practically those already described in speaking of nitrous oxide. In the case of nitrous oxide when used with oxygen, the only after symptom of any moment is that of nausea with or without vomiting. The evil effects of cyanosis and its sequelæ are usually absent after nitrous oxide and oxygen.

Cases VI., a death, p. 123 ; also A, B, and H, pp. 125 and 127, reveal the fact that certain well-marked dangers may arise even when this mixture is employed. As is pointed out below, the claim for safety of nitrous oxide and oxygen as an anæsthetic in brief operations, is not valid in the case of its use for prolonged operations in major surgery.

Experience alone can enable the administrator to regulate the amount of oxygen required for any given case. It should be remembered that the addition of oxygen is simply made to enable a patient to go on breathing nitrous oxide without suffering from oxygen starvation. In other words, oxygen is an adjunct, and not an adjuvant anæsthetic such as is ether, so that as little should be given as is consistent with maintaining the required oxygen tension in the pulmonary air-cells. Thus **full-blooded men** in robust health require less oxygen, **alcoholic subjects** are apt to become excited if oxygen is given at all freely at first. **Children,** the anæmic, and persons in **feeble health,** or who suffer from any disease giving rise to **cyanosis** and **venous engorgement,** especially where the **circulation is feeble,** or the blood pressure unduly high, require more oxygen, and frequently the quantity given must be rapidly increased at the commencement of inhalation, even if the amount is lessened later on. It should be remembered that when a slight excess of oxygen is given the patient is apt to pass into a state of passivity, **and**, although unable or reluctant to move, he yet may cry out and experience painful sensations during the operation, in this case the anæsthesia is really incomplete and extremely transient.

After effects of nitrous oxide with oxygen.—These are the same as those already mentioned as occurred with nitrous oxide.

There is more likelihood of prolonged dazing of the senses, of nausea and vomiting with this combination, and Mr. Edgar Willet has met with prolonged torpor, lasting four days. Sir F. Hewitt records cases of maniacal excitement, but there seems no sufficient evidence to associate such very rare sequelæ causally with the use of nitrous oxide and oxygen. The cases cited below (pp. 121–8) give some interesting examples of the possible dangers of this method and deserve very careful study. There is a real danger threatening its use by those not familiar with it, that, since the signs of anæsthesia are not always easy to recognise, they may be tempted to prolong the administration to a dangerous length.

Nitrous oxide in combination with ether.—When more time is required than nitrous oxide gives, the use of ether in conjunction with the gas is to be recommended. The apparatus which I have found most serviceable is what was called Clover's gas and ether inhaler. The reader is referred to page 173 for particulars of this method.

Nitrous oxide and chloroform.—Although many persons have attempted to establish this succession and some have used the combined vapours, the writer is convinced that either method is dangerous. (See Case of Death No. III., p. 122.)

Nitrous oxide in combination with ethyl chloride.—The employment of nitrous oxide antecedently to ethyl chloride is described in dealing with ethyl chloride. See below, Chapter VI.

Nitrous oxide given from a gas-container.—Where a gas-container is kept, a modification of the above apparatus is in use. A long tube screws on to the efferent pipe of the gas-holder conveying the gas to a bag of 2 or 3 gallons' capacity. This may be connected directly with a face-piece or conveyed to it by another length of tubing, and by using a three-way cock it is easy to combine this apparatus in gear with Clover's small ether inhaler, or with apparatus figured on page 152.

Prolonged nitrous oxide administration.—In cases in which the surgeon requires access to the mouth, nitrous oxide may be administered through the nose, as described above (p. 90). The only difficulty in the management of these cases is, preventing on the one hand cyanosis, and on the other undue admission of air, and these extremes can with practice be avoided. When the operation is not upon the mouth, nose, or buccal cavity, by giving air alternately with nitrous oxide a prolonged anæsthesia

can readily be obtained. As soon as the patient shows the signs of complete narcosis the face-piece is lifted and air admitted for three or four breaths, when it is replaced and more nitrous oxide given. If cyanosis and jactitation are avoided an extremely satisfactory anæsthesia can be indefinitely obtained, only limited indeed by the supply of nitrous oxide. There is apt to be some rigidity in the muscles after a few minutes' inhalation, and the after effects are not always satisfactory, headache and even sickness not uncommonly occurring.

NITROUS OXIDE AND OXYGEN IN MAJOR SURGERY.

Of recent years a great advance has been made in the direction of extending the use of nitrous oxide to the needs of surgery, and to this end elaboration of apparatus has been effected. Dr. Crile's researches into the etiology of shock have led him to believe that the anæsthetic which is employed during a prolonged operation, itself involving shock, may and does provoke the structural changes in the tissues of the nervous system indicative of shock. Comparing the results of shock when nitrous oxide associated with oxygen is used with those consecutive to ether, he believes that the former anæsthetic is less harmful. Teter, in the United States, who has identified himself with this form of anæsthesia, records some thousands of cases if we include minor with major operations. Dr. Gwathmey * has also gained a wide experience and has invented a useful form of apparatus for giving nitrous oxide and oxygen in major surgery. He, with most of those who employ this method, advises the preliminary use of morphine, scopolamine, and atropine and warming of the gases. In this country H. M. Page and H. E. G. Boyle have pursued this form of anæsthesia, and the last-named has invented an apparatus which is described below.

The Teter apparatus consists of a stand supporting four cylinders, two of nitrous oxide and two of oxygen, so that when one cylinder is exhausted a second may be turned on while the empty one is removed and replaced by a full one. In order that the best results may be obtained it is essential that the gases be reduced from a high to a low pressure. This is accom-

* " Anæsthesia," 1914 *passim.*

plished by pressure regulators, which are incorporated in the head of the apparatus. It is possible by this means to obtain a definite proportion of nitrous oxide and oxygen, which will continue to flow in any proportion at the pleasure of the anæsthetist. To obviate the possibility of the nitrous oxide " frosting," steam is forced through the nitrous oxide pressure regulator by means of a mechanism which is part of the vapour warmer.

After the regulators are adjusted to the desired pressure the anæsthetic is controlled by the valves which are directly over the regulators. The dials are marked to show the number of gallons per hour that are being used. The cylinders are attached to these regulators and the regulators connected to the mixing chamber which is fixed to the supporting stand. Directly in front of the mixing chamber is attached the vapour warmer through which all gases must pass. The water in the warmer is kept hot by an electric heater or a spirit lamp. If a spirit lamp is used, the flame is screened so that there is no danger of igniting the ether vapour when it is in use. Vapours passing through the warmer will be delivered to the patient at from 85° to 90° F., which Teter considers is the best temperature for inhalation.

There are times when it is necessary to administer a certain amount of ether with the nitrous oxide and oxygen, for example, when complete relaxation cannot be obtained by using the nitrous oxide and oxygen alone. An ether apparatus that can be used in connexion with the nitrous oxide and oxygen is necessary. The ether attachment is connected directly to the vapour warmer. This consists of an arrangement of special mechanical parts to which a glass jar, holding 10 oz. of ether, is attached. Any amount of ether from 1 to 20 per cent. may be taken up by the nitrous oxide and oxygen. The percentage of ether taken up is controlled by a single handle and the amount is designated on a dial which is on the top of the ether attachment. On the top of this attachment there is also an arrangement for controlling the direction of the outflow of the gases, as there are two outlets for the gases. The tubes throughout the apparatus are wide bored to obviate respiratory strain. The face-piece is made of celluloid, as this allows full view of the patient's face.

To and fro breathing (rebreathing) takes place from the nitrous oxide bag, but cannot contaminate the oxygen in the oxygen

FIG. 24.—The Teter nitrous oxide and oxygen apparatus for major surgery, with ether attachment.

bag. The rebreathing is controlled by using slight positive pressure and the amount of gases allowed to flow from the cylinders. A definite amount is allowed continuously as a definite amount of gases is constantly flowing. By Teter's method of rebreathing about 100 gallons of nitrous oxide and 20 gallons of oxygen are consumed per hour.

Those who employ this method, convinced by the arguments of Professor Yandell Henderson on *acapnia*, recommend systematic rebreathing. To Dr. Gatch * is due the credit for a careful and accurate presentation of the reasons for its adoption within safe limits. For nasal and post-nasal operations a nose-cap is used in place of the celluloid face-piece.

Technique of method.—(*a*) Operations on regions other than the mouth and nose.

The patient is given a hypodermic injection of atropine gr. $\frac{1}{150}$ to gr. $\frac{1}{100}$, morphine gr. $\frac{1}{8}$ to gr. $\frac{1}{6}$, the amount given varying with the views of the administrators. Some authorities, notably Dr. Crile, add scopolamine gr. $\frac{1}{200}$ to gr. $\frac{1}{100}$.† Others again substitute an appropriate dose of omnopon for the morphine. The injection should be made one hour and a half or even two hours before the inhalation; subsequently the patient should be kept very quiet in a darkened room. Mr. Boyle, however, orders the injection half an hour before anæsthetisation.

The apparatus having been tested to see if all the arrangements are working, the mask is placed on the patient's face, and if the valves are acting properly the nitrous oxide is turned on and a gentle stream of oxygen, at first about 2 per cent., is added. It is of the utmost importance that an even flow of gases should be maintained, and to effect this some positive pressure is necessary. If the supply is conveyed to the operating theatre by tubes from fixed tanks, it is easy to compass the required pressure by means of a gas regulator, but if a portable apparatus is being employed, the end aimed at is obtained by having a spiral spring on a sliding collar which rests on the respiratory valve in the face inhaler. The amount of rebreathing is also controlled by this valve. If too much is permitted, the narcosis becomes too slight. The pressure requisite varies in the cases, and lies between 4 m.ms. Hg. and 40

* *Jour. Amer. Med. Assoc.*, March 5, 1910, p. 775.

† The question of the employment of alkaloidal bodies and their dosage is considered more fully in Chapter VII.

m.ms. Hg. If cyanosis appears, more oxygen is allowed to
flow and this gas may at times be given by itself if asphyxial
symptoms are present. Some slight degree of cyanosis is not
regarded as dangerous, and indeed is stated to be desirable. The
vexed question of whether rebreathing is desirable is discussed
below, but it may be here stated that in the author's opinion it
is dangerous and even when restricted within strait limits is not
free from objection.* To ensure accurate information about the
state of the heart during a prolonged administration, a phonen-
doscope is fixed over the cardiac area and in the anæsthetist's
ear. Recovery in normal cases takes place in a few minutes,
but when the circulation and respiration are poor it takes longer.
The induction period occupies two or three minutes. The usual
criteria of the onset of anæsthesia are adopted and the anæs-
thetist is guided by the colour, the character of the respiration,
and condition of the circulation in pushing or withholding oxygen
or nitrous oxide. Unconquerable rigidity was met with only
in 10 per cent. of the cases, and as ether is always at hand this
condition was under control.

(b) All operations on the **upper air-passages,** intranasal,
intraoral, or post-nasal, have been successfully carried out
during the use of this method. In the cases of mouth and nose
operations the anæsthesia is maintained by the nasal cap through
which the gases are inhaled.

Teter has found that mixing nitrous oxide with air instead
of oxygen does not lead to good results. Some points in the
technique require further notice. The essential condition of
an even flow of gases is obtainable by the pressure regulator,
and no advantage is subserved by frequent changes in the
quantities of gases, nor is any one proportion or percentage
uniformly satisfactory in a number of cases. Teter remarks † :
" Numerous factors are responsible for this [lack of uniform
results from uniform percentages], such as type of patient, depth
and frequency of respirations, obstructed air-passages, reflex
from surgical trauma, position of patient, and degree of shock

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* This view was advanced at a meeting of the Medical Society of London,
held October 1917, and by an error of the reporter I was stated to have
said the converse, viz. that I approved of rebreathing. This gloss applies
also to the Report in the *Lancet*, November 3, 1917.

† " The Limitations of Nitrous Oxide with Oxygen as a General Anæs-
thetic," *Jour. Amer. Med. Assoc.*, Nov. 23, 1912.

encountered." He gives as averages $16\frac{2}{3}\%$ of oxygen, 100 gallons of nitrous oxide, and 20 gallons of oxygen for an hour's anæsthesia. A close study of the patient's condition is really the only guide as to the proportions of gases to be used, although it is highly important to have these gases under known pressure, an end attained by pressure valves between the gas-bags and the supply. There is grave danger if the pressure of the gases is allowed to be too great.

Mr. Boyle's apparatus —Mr. Boyle has pursued this method in over 2,000 cases. He gives atropine and morphine and frequently inserts a dental prop between the patient's teeth before the administration. For children he uses only atropine or omits the hypodermic. The bag is filled three parts full of N_2O (4 parts) and oxygen (1 part). The face-piece is fitted accurately, as insuck of air leads to excitement: Rebreathing is commenced almost at once, the valves at the top of the face-piece being closed. He pushes the nitrous oxide to expedite anæsthesia, and if cyanosis appears increases the flow of oxygen for a few seconds. When anæsthesia is complete the amount of nitrous oxide is reduced to 4 and oxygen to 1. Automatic rhythm appears in 4 or 5 minutes. If deeper narcosis is desired, ether is given from the receiver fixed in the circuit. When ether is used as a subsidiary agent some 2% to 8% is usually sufficient.

Mr. A. L. Flemming * has suggested a much simpler inhaler. The gases enter the inhaler by separate channels and are controlled by one valve and rebreathing is provided for. Symptoms of onset of retching or vomiting call for admission of more gas and discontinuance of rebreathing. Cyanosis and muscular twitching Mr. Boyle accepts as signs of over-dosage, and if these occur the mask is removed and oxygen given with, when necessary, the adoption of artificial respiration. As to after effects, Boyle notes that these were trifling, being nausea and vomiting in a few cases, 1% only being sick for more than a few hours. The method he regards as unsuited when absolute relaxation is required, *e.g.* in high abdominal operations and those for disease of the appendix. Boyle finds that 200 gallons of nitrous oxide and 60 gallons of oxygen last for $2\frac{1}{2}$ hours. By a simple adjustment the gases can be given through a tube placed in the nose or

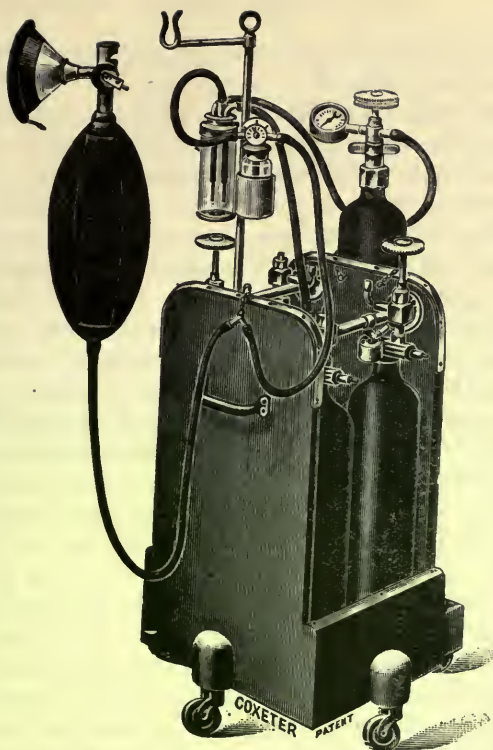* *Proc. Roy. Soc. of Med.*, section "Anæsthetics," March 1913, p. 43.

Fig. 25.—Mr. Boyle's portable gas and oxygen apparatus for prolonged anæsthesia.

The main points about this apparatus are : (1) each cylinder is provided with a fine adjustment reducing valve (the valves are so constructed that they can be fitted to any ordinary English cylinder) ; (2) the principle of the " sight feed " has been adopted ; (3) there is a small spirit lamp for warming the reducing valve to the nitrous oxide cylinder ; (4) a pressure gauge is attached to the oxygen cylinder ; (5) a small re-breathing-bag is attached, together with an ordinary 3-way stopcock and face-piece ; (6) an ether bottle is connected up in the circuit ; (7) the machine has been made in three sizes :—(a) The large size for work abroad. This machine, when fully charged, takes 4 cylinders of 200 gallons, 2 of 500 gallons, and 1 of 40 feet capacity, for oxygen. (b) The next size— the one depicted here—is meant for work in hospitals at home, and carries 4 cylinders of nitrous oxide of 200 gallons each, and a 20-foot cylinder of oxygen. Types (a) and (b) are on wheels. (c) The size for private practice takes 4 cylinders of 100 gallons, 2 of nitrous oxide, and 2 of oxygen. Cylinders of 25 or 50 gallons' capacity can be used with this pattern. This type is so devised that the stand carrying the " sight feed " bottle and the ether bottle can easily be dismounted and securely stowed away between the cylinders. There is a covering lid and carrying handle.

These machines are economical in consumption of gas. 80 gallons of nitrous oxide and 20 gallons of oxygen are usually enough for one hour's continuous anæsthesia.*

* *Lancet*, February 8, 1919.

mouth, thus permitting the use of the apparatus for operations on the mouth or throat.*

Mr. H. M. Page † and Mr. Boyle, from their experience with this method, regard its employment as encouraging.

Page, although in the main adopting Teter's inhaler and method, suggests that a better result is obtained when the gases are led into a bag near the face-piece, as is the case in Dr. Booth-by's inhaler, and that the ether supply be immediately over the face-piece. Among a series of 94 cases of major surgery lasting up to an hour and fifty-five minutes in which only nitrous oxide and oxygen were used, are 51 intraperitoneal operations. He recommends having 300 gallons of nitrous oxide and 90 gallons of oxygen ready for a long case, and advocates rebreathing, both on account of Yandell Henderson's views on acapnia and on the score of economy. His technique includes a preliminary injection of alkaloids, and he considers omnopon gives better results than morphine. Advanced degeneration of the arteries, marked emphysema and all obstructive conditions of the air-passages are, as Mr. Page rightly remarks, contra-indications as regards this method, and perhaps it is not too much to say that until a complete mastery of its technique has been obtained, and it is not easy even for experts, there should be even narrower limits imposed upon its adoption. The cases cited below (p. 121) indicate the danger of acute dilatation of the heart in subjects whose condition might favour such an occurrence, when nitrous oxide and oxygen or air is used for prolonged cases. Post-operative discomforts are markedly lessened by this method, so that diabetes and other cases of toxæmia appear to do better with it than with chloroform or ether or even with spinal anæs-thesia. Mr. Page, indeed, is inclined to think that in states of serious collapse the patients are in better case than when spinal methods are adopted, since the drugs used in the latter procedures act, he thinks, more prejudicially than do nitrous oxide and oxygen. It must, however, be admitted that at present we are not sufficiently informed to speak without some degree of reserve about a method which may prove one of the best at our disposal, but which requires the utmost skill and unceasing atten-tion on the part of the anæsthetist at once to safeguard the

* *Brit. Med. Jour.*, Dec. 21, 1918, p. 684.

† See *West London Medical Journal*, Oct. 1912, and *Proc. Roy. Soc. Med.*, section " Anæsthetics," March 1913, p. 27.

patient, and to ensure an even and tranquil anæsthesia.   A further word of caution is necessary since this method as practised by Dr. Teter and his school is essentially a *mixed method*, and as such all the conditioning factors must be studied.   In practically every case alkaloids are injected before the gases are administered, viz. morphine (or omnopon), scopolamine, and atropine. These, although most valuable, yet exert some distinct effect upon the respiratory centre, and in cases in which the morphine effect predominates there is danger of respiratory failure through the depression of respiration and the cyanosis incident to prolonged flooding of the lungs and pulmonary circulation with the gases nitrous oxide and oxygen.   Boyle has pursued Gwathmey's method and his results are given above.*

The use of the nitrous oxide-oxygen method associated with the employment of local and regional analgesia (Crile's anociassociation) is referred to below.   Its safety is not necessarily that of the anæsthetic, and so is not included in the statements given above.

Safety of Method.—As to the risks associated with the method nothing at all precise can be said.   Undoubtedly, although these gases when given for one inhalation by expert administrators may be considered as practically free from risk for all patients who are not seriously prejudiced by disease or exhaustion, the same immunity cannot be substantiated for prolonged administrations such as are necessary in major surgery; also when alkaloids are employed, and when the patients are subjected to severe trauma and shock, factors other than the anæsthetic enter into the problem.   The type of narcosis inherent in the method is light and evanescent, which embarrasses surgeons who seek profound immobility in the patient.   Cyanosis is commonly associated, and this has its physical counterpart—increased strain upon respiration and circulation, conditions often fraught with danger.   The technique, it must be admitted, is complex and needs great experience and untiring concentration on its details.   As against these considerations we must accept the unhesitating statements of the advocates of the method in the United States and in this country in its favour.   That dangers do and must arise during severe operations, whatever may be the

* Mr. C. T. W. Hirsch has designed a combined gas-oxygen, gas-oxygen‧ ether, and warmed ether apparatus, which is figured and described in the *Lancet*, July 13, 1918.

method of anæsthesia adopted, is so well known that too much importance must not be attached to the statement that serious dangers not infrequently occur during its use. There have been several deaths recorded in the United States which the reporters believe arose directly from the method employed. In Teter's personal practice he has had 11,559 cases of major surgery, 5,537 being of brief duration, 15 minutes or less, 336, 1 to 2 hours, 34, 2 to 3 hours, and 2, 3 to 4 hours; 2,496 oral operations, and to these 16,408 cases of extraction of teeth. One fatality * met with is regarded as having been due to shock and primary cardiac failure. Of the 16 other deaths noted by him, which occurred outside his practice, no detailed description is available; details are not given beyond the statement that only 2 were directly due to the anæsthetic, although it was a contributory cause in others. Some ether also was employed for some of these patients. Dr. J. F. Baldwin,† however, regards nitrous oxide and oxygen as the most dangerous anæsthetic. In 1,200 cases of its use in major surgery in Columbus, Ohio, there were 12 deaths, a mortality of 1%. These occurred in the hands of anæsthetists thoroughly familiar with the method, most falling to a specialist accredited with the widest knowledge of and skill in its use. Dr. Baldwin quotes further fatalities arising outside his personal knowledge; in the practice of Teter (Cleveland) 26; of Mille (Providence) 18; of Roosing 13. Although deaths in such cases are usually attributed to asphyxia, in Dr. Baldwin's experience this was not so. He says in all his cases death was sudden and without warning, resembling the sudden collapse of chloroform fatalities. Connell also deprecates its use since the mortality under it is higher than that under ether. Ochsner would restrict its use to cases of acute pulmonary congestion and acute nephritis. It is probable that British auæsthetists would agree with the writer that the cases referred to by Ochsner are probably best treated by the use of chloroform. The method is certainly inapplicable for children under five years of age, old persons with degeneration of their tissues, for alcoholics and men of great muscular physique.

* 13,000 cases of $N_2O + O_2$ administration, *Jour. Amer. Med. Assoc.*, Aug. 7, 1909, p. 448.

† *Medical Record of New York*, July 29, 1916.

Deaths during Nitrous Oxide Adm...

In the return of deaths under anæsthetics p... Lancet * thirteen under nitrous oxide are given. ... assigned are (1) asphyxia ; (2) fright (imperfect ana... (3) congestion of the lungs, which was not known to be ... when the anæsthetic was administered ; (4) phthisis (last stage), (5) asphyxia due to impaction in the larynx (a) of a broken gag, (b) of a molar tooth ; (6) syncope (three cases), shock of extraction of a tooth in semi-anæsthesia, while in one case the cause of death assigned was tight-lacing interfering with respiration and circulation. Three other cases are given in this Report, in which respiration failed, but the patient's life was saved by prompt recourse being had to artificial respiration. In a paper written by the author † sixteen deaths are tabulated and classified, but some of these are identical with those mentioned above, three additional being supplied. Since the records of these deaths were compiled several more have occurred, but their tabulation appears unnecessary.

The following recorded cases are given as records of accidents which have actually occurred, and are arranged to facilitate the student's study of this subject. It is hoped that such concrete examples will assist the student more than any mere tabulation of dangers and difficulties can possibly do.

CASE I.—In Dr. Maughan's ‡ case the patient was a young woman suffering from an abscessed left tonsil with peritonsillar inflammatory œdema, but no marked dyspnœa, although dysphagia is mentioned. Nitrous oxide was given to her while she sat in a chair, but it was, it is stated, not pushed to any extreme degree. Respiration stopped as soon as the mask was withdrawn and complete obstruction of the air-passage, due to engorgement of the tongue and faucial tissues, developed rapidly. The patient was placed horizontal and laryngo-tracheotomy was performed, and the colour changed from black to normal ; the pupils were contracted. Artificial respiration was started by Howard's method, but the patient ultimately died within nineteen minutes. Inversion is not mentioned. This case appears to be similar

* " Report of the *Lancet* Commission appointed to investigate the subject of the administration of chloroform and other anæsthetics, from the clinical standpoint," 1893, p. 175.   These thirteen deaths occurred in minor surgery.
† *Brit. Dent. Jour.*, Oct. 1895, p. 65.
‡ *Transactions of Society of Anæsthetists*, vol. vi. p. 12.

method of anæsthe..ow (p. 126), and to have been due to septic
importance must utation) of the heart, associated with primary
dangers not in the result of the combination of impaired pul-
several dea culation through the inhalation of nitrous oxide and
believe .e of the heart.
pe...ÅSE II.—In another case the patient suffered from angina
Ludovici, and a house surgeon at a London hospital gave him
nitrous oxide with the view of incising the brawny tissues of
the neck to relieve tension and liberate pus. The nitrous oxide
produced asphyxia through venous engorgement, and, as the
air-passage could not be rapidly opened, death resulted. The
septic factor in this case should be noted. Obviously the choice
of the anæsthetic was at fault.

CASE III.—This case is recorded by Mr. A. Granville.* The
patient, a youth of seventeen, apparently healthy, was given
nitrous oxide and oxygen, and at times became slightly dusky.
After twenty minutes, the youth having apparently resumed
consciousness sufficiently to move and groan, chloroform was
given by an open method. After four or five minutes, the heart's
action became imperceptible, but respiration went on for five
minutes when he died. It was suggested, with what seems great
probability, that the heart muscle dilated acutely under the strain
imposed by the prolonged nitrous oxide and oxygen administra-
tion, and was therefore rendered vulnerable to the action of the
chloroform, which, as Prof. McWilliam has proved, acts not only
as a cardiac depressant but causes acute dilatation of the heart
itself. Dr. Levy's views on ventricular fibrillation should be
considered in connection with this case.

CASE IV.—Mr. G. Norman Bennett † has recorded the follow-
ing death under nitrous oxide. The patient, a boy aged 17,
had diseased glands in the neck, especially in the lower part.
There was no appearance of dyspnœa, and he had within a few
days taken gas without untoward effects. The anæsthetic
was given by a junior hospital officer. Before stertor was heard
the mask was removed and the dental operation commenced.
Shortly afterwards cyanosis appeared, the operation was stopped,
and tongue traction practised, but respiration ceased, then
artificial respiration was adopted, and several spontaneous
breaths were taken. A futile attempt at a low tracheotomy

* _Transactions of Society of Anæsthetists_, vol. ii. p. 175.
† _Op. cit._, vol. vii. p. 1.

was made, but the patient died. It was subsequently discovered that a few weeks previously gas had been given him in the out-patient department, and on this occasion he had nearly died, and was admitted to the hospital as stridor persisted, when it was found that he suffered from lymphadenoma. The necropsy showed that his trachea was surrounded by glands and compressed to half its normal diameter. The heart muscle was degenerated.

CASE V.*—This was also a dental one. The patient was a man aged 33, who suffered from glandular enlargement of his neck, but without dyspnœa. There was nothing abnormal revealed by laryngoscopic examination. An experienced anæs-thetist gave the anæsthetic, and the period of induction revealed nothing unusual. There was no stertor, and the mask was removed after one and a half bagfuls of gas had been inhaled, as some cyanosis appeared. Air was freely admitted throughout. The anæsthesia was complete, but with the extraction of a tooth respiration ceased, and resuscitative measures, although they restored the normal colour, did not save the life. The necropsy showed that the masses of glands had pushed the trachea to the right and somewhat narrowed the air-way. The left pleura was adherent and the right lobe of the thyroid was enlarged and contained areas of suppuration. The glands and thyroid were proved to be carcinomatous.

CASE VI.—A fatality recently occurred in the practice of a skilled anæsthetist when nitrous oxide and oxygen were given to an elderly man for a dental operation. The patient had been seen by a medical man and, although known to have circula-tory trouble, was pronounced to be fit for the anæsthetic. Death without any premonitory signs of danger occurred as the dental operation was completed. The patient suffered from angina pectoris, and the death was no doubt primarily due to this disease.

CASE VII.—In this case the nitrous-oxide-oxygen method was associated with the use of analgesia † (Crile's method). The patient, a man aged 66, was given morphine and scopolamine ¾ hour before gas and oxygen. When unconscious the abdominal tissues were infiltrated with weak novocain and quinine and urea solutions. His general condition was poor. During the

* Narrated by Dr. McCardie, *Transactions Society of Anæsthetists*, vol. vii. p. 21.

† Dr. W. J. McCardie, July 22, 1916, *Brit. Med. Jour.* p. 109 ; cf. *ibid.*, Aug. 5, p. 159 ; also p. 200.

operation he appeared to be dying, the respiration being feeble, the pulse almost imperceptible, and his colour ashen. An hour after being placed in bed he collapsed and died. It is probable that the medullary centres were rendered *ex sanguine* owing to the enfeebled circulation, that the heart became acutely dilated, a condition known to occur under nitrous oxide and oxygen (see case E, p. 126), and as a result the alkaloids exerted a deleterious effect. It is an observed fact which is supported by experiment that when the medullary centres are deprived of depurated blood their resistive power to poisons is lowered, *i.e.* a smaller dose becomes lethal.

CASE VIII.—Death under nitrous oxide-oxygen mixture and stovaine given intrathecally.* The patient, a woman aged 45, was anæmic; operation, hysterectomy; 0˙6 c.cm. stovaine [Billon's solution] was injected, gas-oxygen was given ten minutes later, rebreathing being practised. The apparatus was a bag into which oxygen and nitrous oxide were admitted, the bag being refilled every five minutes. The mixture was pushed to jactitation. The Trendelenburg position was adopted. In 15 minutes vomiting occurred, and later it was repeated coincidentally with the lifting of the uterus from the pelvis. The patient recovered from the first attack, but died when the second syncopal seizure occurred. Dr. Robinson believes the death was due to acute dilatation of the heart incident to the nitrous oxide and oxygen inhalation.† Shock was probably a factor in the collapse, for we know that neither spinal anæsthesia nor nitrous oxide-oxygen anæsthesia is capable of cutting off nerve stimulation from the abdomen to the brain.

DANGERS—ULTIMATE RECOVERY.

The following cases exemplify some of the dangers which, if not peculiar to this anæsthetic, are liable to produce alarm and serious risk to life. It must be remembered that, although

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* Dr. W. E. Robinson, *Brit. Med. Jour.*, Aug. 26, 1916, p. 291.

† Dr. Robinson sums up as follows: "Dr. Dudley Buxton throws out this conjecture [acute dilatation of the heart] in his criticism of Dr. McCardie's case, and from what I saw in my own, I think he is undoubtedly right. We should, then, be guarded in our choice of gas and oxygen, for, though perfectly harmless in the majority of cases, yet, given much anæmia, there is a risk in adding it [the gas and oxygen] to a spinal anæsthetic."

in some instances the results were only indirectly related to the anæsthetic, yet it was an important factor in their development.

CASE A.—A strongly built and healthy man of about 60 had gas and oxygen given him by a skilled anæsthetist, and a tooth was extracted. No unusual symptom occurred during the induction or operation. The return to consciousness was delayed by some minutes ; the patient seemed dazed, and it was found that he could not hold the glass of water and that his speech was thick and indistinct. It was evident that the patient was hemiplegic. The condition was very slight and passed off in a very short time.

CASE B.—A man of about 50 who had for years suffered from cough due to dilatation of bronchi, chronic bronchitis, and some emphysema, was given gas and oxygen without any unusual symptoms. A premolar was extracted, but lost sight of, and on the patient's resuming consciousness he had a fit of coughing. Careful search had been made for the tooth, but without avail. There was no distress in breathing, and not more than the man's usual bouts of coughing. Careful and repeated auscultation and laryngoscopy afforded no evidence of a foreign body in the air-passages, nor were there any symptoms. Many months later, however, after a severe fit of coughing, the tooth was expelled with a good deal of mucopurulent fluid. It is unusual for a foreign body to enter the air-passages without causing urgent dyspnœa, at all events for a time after its entrance. No X-ray was available at the time when this accident took place.

Case C.—A similar occurrence took place at the Royal Dental Hospital when a student was operating. Luckily, on measures being promptly adopted, although the root of the tooth could not be found, it was coughed up before the patient left the hospital. There were no marked signs of respiratory distress.

In the Report of the British Medical Association, July 1900, out of 2,911 N_2O cases 21 are given as complicated ; vomit causing asphyxial symptoms, micturition, and in one defœcation are recorded. The first condition seems to be preventible by abstention from food, while the last two probably reveal a faulty method, as they commonly arise from anoxæmia causing muscular spasms. As regards vomiting, some persons retch and vomit even when they have been quite carefully prepared for the anæsthetic.

CASE D.—Mr. R. W. Collum * has recorded a case in which repeated attempts on different occasions to obtain anæsthesia with nitrous oxide failed. The causes of this are nervousness, the use of too large a gag, since many persons retch directly their jaws are held apart, and an unduly sensitive pharyngeal mucous membrane. The remedies are to use a gargle, spray the throat with a weak solution of cocaine, and insert only a very small prop in the front of the mouth, replacing it by a gag as soon as the induction is complete.

Case E.†—The patient was a delicate girl, the operation avulsion of a toe-nail. The heart and lungs were normal before inhalation. Induction by gas and air was normal, the operation was commenced and the mask withdrawn to admit air. On reapplication, some cyanosis developed, respirations 40 to 50, and engorgement of the neck veins. Half air and half nitrous oxide was given, but the blueness increased and the breathing became slow and shallow, while the pulse grew weak and " running " and very rapid. The pupils were dilated, but reacted to light ; the conjunctival reflex was absent. The apex beat was displaced one inch outside the nipple line, and the heart impulse was felt over a wide area, and over this could be heard a loud blowing systolic murmur conducted outwards to the mid-axillary line. These signs all disappeared within fifteen minutes of the commencement of the induction, the only sequela being headache. Some days subsequently this girl was given chloroform without anything abnormal occurring.

CASE F.‡—The patient, a nurse, suffering from a septic arm, was given gas and air for two minutes. In this case also the apex beat was displaced outwards (for two inches) and a systolic murmur was heard while evidence of acute dilatation was present. See Cases VII. and VIII. (p. 123–4).

CASE G.§—Patient, a girl suffering from a septic leg. Gas and oxygen were given, no cyanosis supervened, but the heart, which was auscultated throughout the inhalation, was found to have rapidly dilated, although no murmur was heard.

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* *Proc. Roy. Soc. Med.*, 1912, section " Anæsthetics," p. 14.

† Reported by Mr. Francis, *Trans. Soc. Anæsthetists*, vol. iv. p. 7.

‡ *Ibid.*, vol. ii. p. 185, and vol. iii. p. 9. Cases mentioned by Mr. H. C. Crouch.

§ Reported by Mr. Francis, *Trans. Soc. Anæsthetists*, vol. ii. p. 185, and vol. iii. p. 9. Second case mentioned by Mr. H. C. Crouch.

CASE H.*—A healthy-looking young woman came to the Royal Dental Hospital, and the presence of a goitre was overlooked. When the anæsthetist gave her gas and air she was enveloped in a mackintosh apron which prevented his noticing the tumour. The induction was normal and the anæsthetic was pushed to allow several teeth to be extracted. In attempting to extract a lower tooth, presumably the tongue was forced back and the lower jaw depressed. The breathing stopped at once, the colour was ashen, the pupils widely dilated, the globes turned up and the conjunctival reflex absent. The gravity of the case was recognised, the patient lifted to the floor and the head *placed in the line of the body*. Respiration was easily restored. In both cases the pressure of the goitre was apparently determined by the position of the head, and the occlusion of the trachea caused extreme engorgement of the veins.

CASE I.—A lad of 16 with a goitre was sent to the Charing Cross Hospital for advice. On reaching the hospital he turned his head to speak to some one, and the pressure of the goitre produced occlusion of the trachea. He was brought in in the last stage of asphyxia and only the prompt opening of his windpipe saved his life. This case is recorded as showing the danger of goitre. The lad was going to the hospital to take gas and his goitre had not been recognised.

CASE K.†—Patient, a man aged 24, suffered from multiple osteo-arthritis, involving both mandibular joints so that the teeth could only be separated for $\frac{1}{3}$ inch.

Operation, removal of teeth and stumps.

Nasal respiration was quite free, so nitrous oxide was given by that route. Slight cyanosis developed after a normal induction, and one stump was extracted. Cyanosis increased, and respiration stopped. The patient was placed on the floor, the mouth opened by force, the tongue pulled forward and the pharynx cleared of viscid mucus. Artificial respiration failed to effect air entrance into the lungs, so tracheotomy was performed, when air entered freely and the patient rapidly recovered. The obstruction in the larynx appeared to be due to venous con-

* *Trans. Soc. Anæsth.*, vol. vii. pp. 37-9. Mr. Carter Braine describes this and the following case in detail, and points out that the experience gained in the one (H.) guided him in his treatment of the second (I.).

† Reported by Mr. H. Relph and Dr. Rood, *Brit. Med. Jour.*, 1910, vol. i. p. 1287.

gestion. Chloroform was given through the tracheotomy tube on the next day and all the stumps successfully removed. Such cases seem therefore to negative the use of nitrous oxide for them, and to indicate the employment of chloroform.

In connexion with these cases that mentioned (on p. 122) and reported by Mr. Granville may be studied, as well as Sir F. Hewitt's case (see p. 98). It would appear that the main dangers to life under gas are those which arise (1) through interference with respiration, and (2) those in which the blood-vessels or heart suffer probably, however, secondarily to respiratory strain.

The cases of foreign bodies entering the air-passages—accidents incidental to the operation—are considered later, so that in this place attention is invited to effects due directly to the anæsthetic, although no doubt the state of the patient at the time of the administration constitutes a contributive or determining factor.

The theory cannot be sustained that septicity is alone responsible for the acute dilatation of the heart resulting from the respiratory strain produced by the entrance of a foreign gas into the blood-stream and the lessening of the oxygen supply through the loss of carrying power of the erythrocytes, since in some instances no septic condition was present. However, we know that both anæmic and septic conditions cause degenerative changes in the myocardium, and this probably renders the heart predisposed to acute dilatation, even when no obvious asphyxial complication co-exists. It seems likely that when slight faintness or even syncope follows the use of this anæsthetic an acute dilatation is present although it is not appreciated. In prolonged inhalation, such as by the nasal or other methods, such a development would be most liable to occur, so that its rarity indicates that it is by no means a constant danger, but is rather a possible accident to be kept in mind in the case of certain types of persons. The deaths arising through pressure upon the trachea by masses of glands or by a goitre demonstrate two points : (1) the absolute necessity for preliminary examination of the patient's fauces and neck *in all cases*, and (2) the substitution of some other anæsthetic, probably chloroform, in severe forms of such conditions. The mere absence of dyspnœa during consciousness is no criterion of safety since it is often absent, and severe dyspnœa may develop as soon as the muscles

fail to maintain the trachea in the position of safety. In goitrous patients avoidance of cyanosis cannot be ensured and when it is present it produces venous engorgement, and a vicious circle is engendered which leads to death.

A general summary of the actual causes of the deaths may be useful as supplementing the observations which have already been made. In most cases the death could not have occurred simply as a result of nitrous oxide inhalation. In at least three cases the patient suffered from conditions which rendered the upper air-ways constricted, and liable to complete closure if any marked venous engorgement arose, such as might occur during the inhalation of nitrous oxide. Œdema, inflammatory swelling affecting the tonsils, tongue, larynx, and adjacent tissues, are extremely likely to cause asphyxia when nitrous oxide is inhaled; the patients suffering from such conditions are not satisfactory subjects for this anæsthetic. A goitre or enlarged glands may produce dangerous symptoms. Spasm of the larynx has been reported and its possible supervention, even without the mechanical irritation caused by fragments of teeth, etc., must be remembered, as death has resulted without impaction of foreign bodies in the larynx when the patient was under nitrous oxide. This spasmodic closure probably was the cause of one of the deaths, and followed inhaling impure and irritating gas. Cough and difficulty of respiration should always suggest this possible complication, and the gas should be tested before the patient is allowed to inhale it, if the first attempt causes severe laryngeal irritation. The administrator can easily determine whether the gas is impure by himself inhaling a few breaths of it. As to syncope, undoubtedly deaths have arisen from heart failure; these result either from fright and incomplete anæsthesia alone, or more usually these states are contributory to inducing cardiac failure in the anæmic and feeble, due, it seems probable when the cases given above are considered, to acute dilatation of the heart.

Suffocation, either from foreign bodies, *e.g.* vomit, sponges, etc., blocking the air-passages, has in some of the cases caused death, a death which arose from mechanical causes and not from the action of the anæsthetic.

It is difficult to be sure whether nitrous oxide by itself has ever been directly the cause of death, although it may certainly cause death when used by inexperienced persons. If it is used

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in an impure form, or if given to persons suffering from some asphyxial symptoms in whom respiration is already seriously interfered with, nitrous oxide is undoubtedly a dangerous anæsthetic, and potent to lead to serious results. The heart seems seldom primarily affected, but in the feeble and asthenic it is certainly liable to fail should the respiration be in any way hampered, so that syncope can thus be brought about and may prove fatal. An undeniable danger exists in the case of persons who are alcoholic or have taken alcohol immediately before inhaling an anæsthetic. They become greatly excited, and struggle, so that, owing to the tonic rigidity of the muscles concerned in respiration, a severe strain is imposed upon respiration and the heart, which may determine a rupture of a blood-vessel or overfilling of the right ventricle, with consequent syncope.

Summary of the Uses and Management of Nitrous Oxide in Minor and Major Surgery.

Preparation.—No special preparation is required; food is best avoided for some time before inhalation, and delicate, stout, and elderly persons should be cautioned not to fatigue themselves, or to hastily climb upstairs before taking it.

Clothing should be sufficiently loose to permit full breathing and the *neck coverings* must be removed. Abdominal and hernia belts are best left on. I have known a hernia to descend during the straining such as may occur in nervous people.

Posture is always most important, and, as was pointed out above, should be comfortable and easy, with the head in the body's axis, and none of the muscles in tension. If a protecting mackintosh is laid over the neck and chest its arrangement should not obscure a complete view of the patient's respiration. Struggling is usually due to unnecessary forcing of the anæsthetic; this should be avoided, but when the patient's breathing assumes its normal force and rhythm, the anæsthetic may be pressed. If oxygen or air is given with the nitrous oxide, and one or the other should always be employed, the indication for admission of either is the appearance of cyanosis or rapid supervention of subsultus and stertor. This plan lengthens the period of induction, so permitting a larger amount of the anæsthetic to enter the circulation. When the mask

is removed and the operation is commenced, the anæsthetist must watch the patient's colour and respiration and at the same time take any steps necessary to avoid accidents associated with the operation. He fixes the head with his right hand, and as soon as his left has hung the inhaler within reach, it can be used to hold a mouth-spoon behind the region of extraction to catch stumps or teeth. A gag must be at hand, as its insertion will be necessary if the dental prop slips, or in the event of the operator operating consecutively on each side of the mouth. Cyanosis is usually due to pushing back of the tongue by the operator's fingers, and, provided some respiration takes place, this may be ignored in healthy subjects for one or two respirations, but if the patient is feeble or the heart of doubtful vigour, air must be admitted by the fingers being lifted. Pushing forward the mandible from behind the angle will usually lift the tongue and start a respiration. If while extracting lower teeth the chin is forced down on to the chest some obstruction to respiration will occur ; when this is so, the correct position of the head and of the jaw must be restored. The blood either from the nose, or from the gums in multiple extractions, is apt to flow back to the epiglottis unless care is taken to keep the head straight or even a little forward. A sterilised swab of gauze or a marine sponge should be at hand to remove the blood, which otherwise may interfere with breathing, or if it is swallowed may occasion nausea and vomiting. If a sponge is placed over the gums after extraction it must be secured by a long looped string outside the mouth. If the dental prop has slipped and the teeth become clenched great care must be taken to introduce the closed gag somewhere in the region of the molars or premolars, by preference at the spot where there is a gap. If put between the incisors and pressure is used these teeth may be forced out. In cases of severe trismus a very small wedge secured outside the mouth will usually enable an anæsthetist to slip in a gag and separate the jaws when unconsciousness has supervened.

The period of recovery is seldom marked by any noticeable incidents. Pallor, or feeling " weak " and " sleepy " is often complained of, and then the patient should be persuaded to inspire deeply, or, if necessary, the head can be lowered. A patient should never be hurried out of the chair or be allowed to stand, for some minutes after the inhalation. Weakly persons

or those who " feel bad " had better be kept lying on a sofa for half an hour.

If remedial measures such as artificial respiration, laryngotomy, and so on have to be undertaken, the patient should be placed on the floor, as these procedures cannot be carried out effectually in a dental chair. The anæsthetist should assure himself, before the patient's recovery, that the jaw has not been subluxated or dislocated. Props should not be removed, except in emergencies, until the patient is conscious.

CHAPTER IV.

ETHER.

The Methods of using It.

Intravenous Infusion of Hedonal.

Ether or ethyl oxide was discovered in 1540 by Valerius Cordus and named by him *oleum vitrioli dulce*. In 1730 Frobenius substituted its present designation. Ethyl ether must be carefully distinguished from " compound anæsthetic ether," a mixture of amyl and ethyl ether which is used solely for producing local anæsthesia.* " Compound anæsthetic ether " cannot be safely used for producing general anæsthesia—indeed, the attempt has resulted in fatal accidents.

Chemical and physical properties.—Ether, known also as sulphuric ether, is ethyl oxide $(C_2H_5)_2O$. It is prepared by the action of sulphuric acid on alcohol. When pure it is a colourless, transparent, mobile liquid with a penetrating odour. Boiling-point, 35° C. Specific gravity, 0·720.

Numerous qualities and varieties of ether are sold. These fall into two groups :—

(*a*) Those prepared from duty-paid rectified spirit ;

(*b*) Those prepared from industrial alcohol, which is exempt from duty, and contains 3 per cent. (war-time) of wood naphtha.

The presence of methyl alcohol in the wood naphtha used in the industrial alcohol causes the ether derived therefrom to contain methyl oxide $(CH_3)_2O$, and methyl-ethyl oxide $CH_3.O.C_2H_5$. These bodies have a lower boiling-point and specific gravity than ethyl oxide, hence the so-called " methylated " ethers commence

* See Chapter XI.

to boil below 35° C., and have a lower specific gravity than the corresponding product prepared from pure alcohol. The variations in the specific gravity of commercial ethers is also caused by the presence of varying proportions of alcohol and water.

Some discussion has arisen with regard to the relative merits of ether used as an anæsthetic when it is prepared from ethylic or from methylic alcohol. Provided these ethers are carefully prepared and thoroughly purified, they give practically equally good results. I have employed the methylated ether for years and have found it satisfactory.

The following are the chief qualities sold by manufacturers :—
Ether Pure 0·720.

    Pure ether from rectified spirit. Nearly free from water.
Ether Pure 0·735.

    Ether from rectified spirit, but containing nearly 10 per cent. of water and alcohol.
Ether Meth. 0·717.

    Prepared from industrial spirit. Nearly anhydrous, but contains methyl oxide. It commences to boil at about 20° C.
Ether Meth. 0·720.

    Prepared from industrial spirit. It contains small varying proportions of alcohol and water. It usually contains traces of aldehyde and peroxides.
Ether Meth. Purif. 0·720.

    Prepared from industrial spirit, but is free from impurities, and should comply with the tests given below.
Ether Meth. 0·730 and Ether Meth. 0·735.

    Prepared from industrial spirit. They contain water and alcohol, and are intended to be used as solvents and for technical purposes.

Only the two varieties (i) Ether Purificatus, prepared from rectified spirit sp. gr. 0·720, and (ii) Ether Meth. Purificatus sp. gr. 0·720, prepared from industrial spirit, should be employed for producing general anæsthesia, as the others are either impure or altogether unsuited for this purpose.

The following are the principal tests for ether intended to be used as a general anæsthetic :—

Residue.—20 c.c. allowed to evaporate from a glass dish should leave no residue. The dish should be warmed on a water-bath to dispel the film of moisture which is attracted from the air by the ether during evaporation.

"*Smell*" *Test*.—When 10 c.c. or 20 c.c. are poured over a filter-paper and allowed to evaporate, it should not be possible to detect any foreign odour at any stage of the evaporation, and the paper should be quite odourless after complete evaporation of the ether.

Free Acid.—Sulphurous acid. When 5 c.c. are allowed to evaporate spontaneously in a glass dish, the film of moisture left should not redden or bleach blue litmus-paper.

Water.—Anhydrous ether forms a clear mixture with an equal volume of carbon bisulphide. Ether Meth. Purif. 0·720 often contains traces of water and does not comply with this test.

Aldehyde.—When kept in contact with small, freshly broken pieces of potassium hydroxide, in a well-stoppered white glass bottle in the dark, no yellow colouration should be developed within one hour.

Peroxides.—When mixed with one-tenth of its volume of freshly prepared 10 per cent. solution of potassium iodide and kept in the dark, being shaken frequently, ether should not develop a yellow colour within three hours.

General properties and uses.—Ether is an exhilarant and finally an anæsthetic.*

As a general anæsthetic ether possesses an advantage over nitrous oxide gas in so far as it produces a more prolonged and a more profound narcosis. It is believed to be safer than chloroform as it is a very weak protoplasm poison, if one at all, and does not prejudicially affect the heart. It raises blood-pressure. It is therefore to be recommended for general use. The allegation that ether produces more dangerous pulmonary after-effects than chloroform has been urged, but cannot be said to be entirely proved, and many of the reputed disadvantages of ether are undoubtedly due to faulty administration rather than to any inherent peril in its action upon the tissues. This point will be considered again when the after-effects and sequelæ are considered. Probably the greatest danger which may arise through the incautious use of ether is the exhaustion following undue stimulation, but strangely enough this aspect of the matter has received but slight attention : it will be dealt with later on (p. 215). Safe as ether administration undoubtedly is, its careless use, as when an unnecessarily large quantity is employed, gives rise to ether toxæmia, a state distinct from ether anæsthesia.

It must, however, be borne in mind that ether has its limita-

* For the use of ether to produce local anæsthesia, see Chapter XI.

tions, a fact which is often overlooked, with the result that failure and disappointment follow in certain cases, both of which might have been avoided had a more careful selection of the anæsthetic been made.

Contra-indications.—Cases in which ether should not be used except by special methods, *e.g.* intrapharyngeal inspiration, intratracheal insufflation, or intravenous infusion :—

1. In protracted operations about the mouth, jaws, nose, or pharynx, which necessitate the mouth and nose being uncovered. Since consciousness rapidly returns when the supply of ether is discontinued, as it must be when routine methods are pursued, so that there is not time for prolonged surgical procedure.

2. In all operations which require the employment of the actual cautery, or lighted candles, lamps, etc., near the mouth.

In the following conditions the advisability of using ether ought to be carefully weighed :—

Persons who are suffering from *bronchitis*, the *emphysematous* (if the condition be very pronounced), and as a rule *asthmatics*, bear ether badly, since it excites cough and may clog the bronchial tubes with a quantity of excessive secretion. On the other hand, ether often assists the breathing of asthmatics if it is pure and copiously diluted with air. The hypodermic injection of atropine before the inhalation prevents excessive salivation and bronchorrhœa.

In *renal disease*, when extensive, ether is said to induce nephritis and even suppression of urine, so that if given at all in these cases it should be used with the utmost caution.

The vascular excitement to which ether gives rise, contra-indicates its employment for persons with an unduly high blood-pressure and for those who have *rigid* and *atheromatous arteries*, or in whom circulatory perturbation is likely to be harmful, especially if the method employed imposes some air exclusion, since the added asphyxial condition will still further raise the blood-pressure. It is obvious that when *cerebral hæmorrhage* from rupture of an artery has once occurred, ether might, by increasing arterial tension, induce a repetition of so dangerous an accident. Some few instances of this have occurred.

In *infants* and *very young children* ether may sometimes produce pulmonary trouble from its irritating effects upon the delicate mucous membrane of the respiratory tract.

Although, in selecting an anæsthetic, it is well to weigh these considerations, yet I think few of them are insuperable objections to ether, except perhaps in very marked cases of disease.

In *tropical climates* it is difficult to obtain and to keep ether, and also to administer it satisfactorily.

As ether often provokes rapid breathing and not infrequently may provoke coughing before complete anæsthesia has been obtained, it should not be used when these are prejudicial to the patient, or to the success of the operation—for example, in some operations on the eyes. Many surgeons object to ether in abdominal operations, when given by the older methods, both on account of the inconvenience arising from the rapid laboured breathing often caused by it, and because they consider the patients are especially liable to pulmonary troubles after the operation. As will be seen in the sequel, the associated employment of alkaloids with ether, and the adoption of an open or the intratracheal method, enable the anæsthetist to surmount many of these difficulties, so that the majority of abdominal operations at the present time are performed under ether. It is not, however, wise to adopt ether as a routine anæsthetic for such cases, since in many instances the well-being of the patient after the operation is certainly prejudiced by employing ether. Chloroform, assuming it is given by scientific methods, is for many persons a safer anæsthetic.

In *operations upon the brain* or spinal cord, when turgescence and dilatation of the blood-vessels are undesirable, ether should not as a rule be used ; and according to Prof. Wood it is contraindicated in the presence of brain tumours. Even in this instance some anæsthetists adopt ether, selecting the open method. In the U.S.A. ether is constantly chosen in operations upon the central nervous system, sometimes by an intratracheal insufflation, sometimes by the colonic ether-oil method, and sometimes by naso-oral inhalation. My personal experience of brain surgery induces me to prefer the use of chloroform, more especially in cases of cerebellar tumour.

PHYSIOLOGICAL ACTION OF ETHER.

Hermann asserted that ether causes the destruction of the red blood corpuscles. Dr. Da Costa,* of Philadelphia, has found

* " The Blood Alterations in Ether Anæsthesia," *Medical News*, March 1895.

that it produces a marked diminution in the hæmoglobin, more especially in persons whose blood is pre-existently diseased (*e.g.* anæmia, chlorosis, etc.). More recent work undertaken by Engelhardt, Mulzer, and others, confirms the earlier researches. Concentration of the ether causes hæmolysis at lower temperatures. As Bloch has shown, the length of time during which the tissues are subjected to the influence of concentrated or even ordinary strengths of ether vapour is of importance, since its harmful action varies directly with its concentration and the duration of its action upon tissue protoplasm. Bernard showed that infusoria were readily influenced by ether, and Sternberg has demonstrated that it destroys pathogenic bacteria. Graham states that large quantities of ether delay phagocytosis for days or even weeks.

Prof. F. Keeble * has discussed the effects of anæsthetics upon the lower organisms. Thus ether will produce cessation of the biochemical functions of both animal and vegetable protoplasm, but will only destroy it when used in great strength and for a prolonged period. Certain bacteria are positively chemiotactic towards ether (Rothert). Nathanson found that ether causes cells usually dividing by karyokinesis to become subject to amitotic division. According to Wilson the eggs of Toxopneustes while under the influence of ether lose their asters. The effects of ether upon flowering plants, although interesting, are hardly germane to our present subject, so readers interested in the subject should refer to Prof. Keeble's paper, which supplies an excellent bibliography of the subject.

When the pure vapour is first inhaled it induces a burning sensation in the mouth, pharynx, and throat, and a feeling of impending suffocation, which varies directly as the strength of the vapour inhaled. It appears to act in two ways : indirectly through the nerve centres as a powerful deliriant and anæsthetic, and directly upon the endings of the nerves supplying the pharynx and respiratory tract. Thus, it increases the flow of saliva, and causes considerable discharge of watery secretion from the mucous membrane of the respiratory tract. Its extreme volatility makes it exert a marked cooling action upon the skin and mucous membranes when it is brought into contact with them ; and the vapour may, if injudiciously employed, excite catarrh. Ether is absorbed both by the mucous membrane of the respiratory

* *Trans. Soc. Anæsth.*, vol. viii. p. 31.

tract and by that of other mucous surfaces, *e.g.* the colon and rectum. When ether vapour is given by the bowel, the vapour is perceptible in the breath after a few minutes. When delivered directly into the trachea as by the intratracheal insufflation method the action is very rapid, and unless the vapour is warmed before entering, it cools the lungs more than when it is inhaled in the ordinary way, and so lowers body temperature. This is due to the fact that the oral, nasal, and pharyngeal cavities, which usually warm the ether when inhaled, are in this method not traversed by the anæsthetic. Ether, when infused with saline into the blood-stream, produces narcosis very rapidly. It can be recognised in the patient's breath within a minute of its entrance into the vein.

Intramuscular injections of ether also produce narcosis, but the absorption is less rapid than when introduced by other channels.

The nervous system during etherisation becomes profoundly affected. The cerebrum first succumbs. Excitement and hallucinations occur, the patient believing that he is engaged in some active exercise ; he often grows pugnacious or amatory, or pursues his habitual work or pastime ; he may struggle and cry out. Soon his speech becomes thick and inarticulate, his struggles cease, and his mind no longer controls his movements. The *sensory nerves* of the spinal cord then fail to convey impressions from without, although stimulation of the motor nerves induces movement. Later, the motor nerves also cease to respond, save to powerful electrical excitation (Longet). Waller has shown that isolated nerve is directly influenced by ether, but that ether is about seven times less potent in this respect than chloroform. The *medulla oblongata* becomes next affected ; at first sensory impressions fail to reach it, finally its centres become paralysed, respiration is first arrested and then the heart ceases to beat. It appears that these results are due to the direct action of ether conveyed by the blood to the nervous centres producing intoxication since they occur after section of the pneumogastric nerves, or when the anæsthetic is injected directly into the veins. Hence it would seem that ether, directly affecting the centres, acts first as a stimulant, and later as a paralysant. When spontaneous breathing has ceased, if artificial respiration is maintained, the heart will continue to beat for a prolonged period, and this in spite of very large quantities of

ether being taken, since ether is not in the ordinary sense of
the term a protoplasm poison, or, perhaps it is more consonant
with our present knowledge to say, it is an extremely weak one.
It kills by suppressing biochemical processes, by rendering the
vital centres unable to take up oxygen, or by exhausting them
through over-stimulation. In most cases measures adopted to
resuscitate the patient will succeed if they are not unduly
delayed.

Ether narcosis may be divided into five degrees (Snow) as
in the case of chloroform, although it is practically impossible
to recognise the individual degrees, since they rapidly merge into
each other.

The phenomena of these may be summarised as follows :—

(1) All the effects that exist while consciousness is still present ;
a burning pungent taste and smell ; buzzing or singing in the
ears ; inability to recognise objects in the proper places, as they
appear distant and unduly large ; the speech of bystanders often
imperfectly understood and misapplied. (2) The mental faculties
become impaired but are not suspended, illusion, semi-delirium,
excitement, and muscular movements appear but are of a
subjective rather than of an objective significance. Impairment
of sensibility exists, and pain, even if slightly felt, is seldom
remembered as pain upon awakening. This is probably the
condition of which the French surgeon Péan wrote when he
described patients who moved freely and appeared conscious,
but were nevertheless oblivious of the surgeon's knife. This
state is similar to the unconsciousness of painful stimuli evinced
by persons intoxicated by alcohol. Rigidity and muscular spasm
usually appear as the patient passes into the next degree. Of
especial significance is spasm of the larynx and of the respiratory
muscles ; however, laryngeal spasm under ether is more com-
monly the result of a sudden presentation of strong ether vapour
to a larynx whose sensibility has not been lessened by gradual
anæsthetisation. (3) All the mental faculties are in abeyance,
the muscles relax, and no movement of the voluntary muscles
takes place, nor is any pain felt. Occasionally patients will
wrinkle up their brows or even moan throughout an operation,
but these are not necessarily indications of pain. (4) Paresis
of the centres of the *medulla oblongata* supervenes with gradual
failure first of respiration and then of circulation ; and (5) death
results from destruction of these centres and consequent stopping

of the heart. Patients may be restored during the fourth degree by the performance of artificial respiration, but probably not when the circulation has ceased in the fifth. Recovery can undoubtedly follow even when *apparent* arrest of the heart has taken place, since the circulation may be carried on, although feebly, when the heart appears not to be acting.

Duret * divided ether narcosis into two periods :—(1) Anæsthetic sleep—cerebral excitation, followed by abolition of cerebral function and disappearance of sensibility ; and (2) anæsthesia—muscular resolution and abolition of reflexes. Dastre points out that the order in which sensation is lost is one of primary importance. The following is the succession in which sensibility disappears :—that of the integument of limbs and trunk, next that of the face, then that of the nasal mucous membrane, followed by that of the eyes, then that of the organs of sense, the ear being the last to fail. It may be noted that the genital organs and rectal mucous membrane retain sensibility to stimuli for a very prolonged period. The knee jerk is increased in the early stage of etherisation (Eulenberg), and even in the second degree ankle and knee clonus are apt to develop, and as a rule more profound narcosis will cause the phenomena to cease. A curious and troublesome phenomenon of ether narcosis is ether tremor.† It comes on at the end of induction, the whole limb shakes, often with great violence, and the tremor is increased by any attempt to control it. I have seen it occur even when conjunctival reflex was completely lost and the respiration was slightly stertorous. It is rather more common in the lighter narcosis characteristic of "open ether" than in the more profound narcosis reached when a closed method is pursued (see below, p. 145).

RESPIRATORY SYSTEM.

In the rhythm of *respiration*, ether brings about marked changes. If the full strength of ether vapour be allowed to impinge upon the glottis, the adductor muscles are thrown into spasm, and the rima glottidis becomes temporarily closed. Ether

* Quoted by Prof. Dastre, " Les Anæsthétiques," p. 77.
† This is allied to the condition known as " kidney clonus," which is especially liable to be elicited during operations on the kidney when the patient is under ether.

may thus cause laryngeal spasm (Kratschmer). Indeed, ether has been shown by Victor Horsley and Semon to exert a marked local action upon the laryngeal muscles. These observers have demonstrated that this differs according to the depth of the narcosis induced. Slight narcosis causes adduction, while deep etherisation produces abduction, of the vocal cords, and these results obtain alike with strong or weak faradic currents, and whether the recurrent laryngeal nerve is divided or left intact.

During ether inhalation the respirations are at first hurried and deep, subsequently they become slower and more shallow, and eventually, if ether is pushed to a dangerous extent, cease altogether. Provided the respiratory acceleration is only moderate, it assists circulation and so raises blood-pressure; if excessive, it has the opposite effect, and by increased lung ventilation lowers the tension of carbon dioxide, producing an acapnic condition.* Failure of respiration is rapidly followed by cessation of the heart-beat. Such effects are also produced by exhaustion following over-stimulation, and this should be kept constantly in mind when an operation is likely to be greatly prolonged. This slowing and final cessation of respiration appear to be due ultimately to poisoning of the respiratory centre.

In some patients who are apparently free from bronchial catarrh, the use of ether sets up a profuse secretion of thick tenaceous mucus which hampers breathing. This is especially the case with excessive smokers. For such persons it is well to avoid ether unless atropine has been injected before inhalation, or if the complication is only observed after anæsthesia is established, to substitute chloroform or the A.C. mixture for ether, when as a rule the inconvenience disappears. Before effecting this change, however, the mucus should be sponged out and all signs of respiratory difficulty should have passed off.

Wood points out that irregularity and even cessation of respiration may occur in the early stages of etherisation, and is due to irritation of the nerve fibres of the trigeminus and vagus; this inhibition may be overcome by deepening the anæsthesia and so annulling the reflex. Such respiratory perturbations must of course be carefully distinguished from those due to over-narcotisation of the medulla, which can only occur late and in profound narcosis.

* Embley, *Bio. Chem. Jour.*, vol. v. Nos. 1, 2, 3.

CIRCULATORY SYSTEM.

The *heart's action* is at first excited and increased in force ; later it quiets down, and may even grow somewhat weaker than normal ; though such weakening is always trifling. The *blood-pressure* is increased until very deep narcosis is present, when a slight fall occurs. The peripheral vascular dilatation showing itself in flushing and rubescence of the skin, together with sweating and a roseolous rash, is the cause of this fall in blood-pressure. The presence of this ETHER RASH is pretty constant, but occurs more commonly in women and children. It usually is first seen about the neck and shoulders, but may cover the arms, the chest, and even extend to the thighs. It lasts for a few minutes, sometimes ten or fifteen. It has probably no significance beyond showing the action of ether upon the sympathetic system. Its appearance is usually synchronous with the relaxation of the muscles. Embley * has worked out with great care the effects of ether upon the circulatory system. He finds that blood-pressure falls if measures are not taken to prevent peripheral dilatation of the vessels, but when ether is given by a closed inhaler (*e.g.* Clover's), this fall is corrected by the limitation of air incident to its use and the maintenance of the tension of carbon dioxide. In high concentration ether may undoubtedly lead to heart standstill, but the amount of ether in the blood during surgical anæsthesia does not paralyse the heart in a healthy subject. Slowing of the heart does not occur after section of the vagi, although the vagal centre is primarily excited by ether, but ether very rapidly depresses the vagal mechanism so that inhibition of the heart is less likely to occur under this anæsthetic than under chloroform, and indeed does not arise unless the blood-pressure has fallen very low, and even then is transitory. The fall of blood-pressure under ether is marked, but is due not to enfeeblement of the distributing system, but to the peripheral dilatation. This fact explains why etherised patients are peculiarly sensitive to alteration in the axial position of the body. The " head up " position suddenly effected when the blood-pressure has already fallen may cause further depression even to zero. Ether causes great relaxation of the arteries due to its effect upon the peripheral vascular mechanism, since the vaso-dilator centre is slightly affected. Depressor reflexes so

* *Op. cit.*

common under chloroform and due to stimulation of sensory nerves (trauma) are, it is stated, absent under ether. Ventricular fibrillation does not, according to Levy, occur under ether.

The Kidneys.

Ether appears to act as an irritant to the *kidneys*, although healthy kidneys are but little affected by it. Statistics show that pre-existing albuminuria is slightly increased by ether, but that chloroform is more likely to cause albuminuria in those who have presumably healthy kidneys.* The amount of renal derangement is certainly dependent very largely upon the quantity of the anæsthetic which is employed. As less chloroform will produce and maintain anæsthesia when given from an efficient regulating inhaler, it is better in prolonged operations upon the kidneys, or in the case of patients whose kidneys are extensively diseased, to rely mainly upon chloroform or the A.C. mixture. There is no objection in most instances to inducing anæsthesia by nitrous oxide gas and ether, and maintaining it by chloroform or a mixture. The actual damage done to the renal tissues is greater under chloroform than under ether and more persistent. The anuria often attributed to ether after prolonged and severe operations upon the abdominal or pelvic viscera is probably as much the result of trauma, or " insult to tissue," as of the anæsthetic. However, in such cases, limitation of the quantity of anæsthetic used, and strict avoidance of asphyxiation, as by the use of oxygen, are most important.

The Muscular System.

Under ether the *muscles* at first become rigid and firmly extended, but later these conditions give place to extreme flaccidity ; in some patients the muscles maintain their rigidity much longer than in others, while there is a difference in the time which muscles in various regions take to relax. Snow pointed out

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* On the other hand, Drs. Thomson and Kemp have shown, by experiments on dogs, that albuminuria with lessening of the amount of urine occurs after ether inhalation, but only slight albuminuria without suppression of urine after chloroform inhalation. As I have pointed out, these results do not agree with those at which I have arrived when investigating this matter with the aid of Dr. Levy. I think that probably excessive doses of ether were employed by Drs. Thomson and Kemp, and as a result toxic effects were produced.

that although chloroform produced some degree of muscular relaxation sooner than did ether, yet the most complete flaccidity resulted when ether was used, provided time was allowed for its development. I am entirely in accord with this statement. It is, I think, very common for prolonged muscular rigidity to result from asphyxial conditions, and when these are prevented or alleviated by giving inhalations of oxygen, rigidity under ether rapidly disappears.

CLONUS or TREMOR is a phenomenon of light narcosis, and, although it may occur under chloroform, is usually associated with ether. It affects one or both lower limbs, and if any attempt is made to control the movements, which resemble those incident to the urethral rigor, it becomes extremely violent. The movements disappear, when deeper narcosis is superinduced, and this end is most rapidly attained by changing the anæsthetic to chloroform for a few minutes. Gwathmey states that ether clonus appears usually in the second degree of narcosis, when the patient is resuming consciousness. This is not my experience, for I have found it to supervene early in the third degree, and during induction, although less commonly it may come on after recovery from anæsthesia. Experimenting on muscle, Dr. Ringer and the writer found that in frogs the vitality of involuntary muscle persisted far longer when perfused with solutions of ether than with solutions of chloroform. Peristalsis, although lessened, is not abrogated, even when death is induced by ether.

The late Dr. L. J. Rutherford pointed out that the activity of the lacrimal glands affords a valuable sign of the degree of narcosis present in any case. The secretion in the case of ether, *i.e.* provided no atropine effect complicates the case, is profuse, and pools of fluid are seen at the inner canthi. When the corneal reflex is abolished, the eye becomes dry and profound narcosis exists. If an overdose is present this dryness warns of the state, but if vomiting is imminent, although the corneal reflex is hardly to be elicited, the canthic pools will indicate that the patient is coming out of the anæsthetic state. The pupils vary much in size under ether, and so afford no reliable guide. However, wide dilatation, with lessening of the light reflex and smearing of the ocular globes with mucus, indicate overdosage.

The *body temperature* is reduced under ether ; Kappeler fixes a minimum at ·3° C., and a maximum at 1·5° C. (·5°—2·7° F.). Ether increases the secretions, with perhaps the exception of

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that of the kidneys. Elimination takes place rapidly and is
mainly effected by the lungs.

Signs of Returning Consciousness.

These may be briefly stated to be : The respiration becomes
slow and lung ventilation much decreased ; the face grows pale
and often profuse sweating occurs ; the slow nystagmic move-
ment of the eyes is stayed, but becomes more marked as the
patient becomes more conscious ; the lid reflex may return, but
ocular phenomena are at first almost in abeyance. The pupil
is commonly dilated, especially after a prolonged administration.
Lacrimation is increased. One of the earliest signs is the advent
of swallowing movements, which may be followed by slight
retching or even the ejection of some mucus by vomiting.
Moaning sometimes is heard, but phonation is rare, and any
sounds indicative of feeling pain are subjective, and are seldom
if ever remembered as sensations of pain.

Toxic effects due to overdose are in contrast to the above :
they are great pallor, or, commonly, duskiness, feeble, jerky
breathing, a very compressible pulse, at times intermittent.
The eyes are commonly open, the pupils widely dilated, and the
reflexes, including that to light, disappear. The conjunctiva is
dry and smeared with mucus, the skin is cold and blanched.
Death due directly to the anæsthetic is rare under ether—that
is, in patients who are not seriously exhausted by antecedent
disease or shock.

Methods of administering Ether.

Ether may be given (1) by itself ; (2) in succession to other
drugs (a) after alkaloids, e.g. atropine with or without morphine
and scopolamine ; (b) following some other general anæsthetic,
i.e. nitrous oxide, ethyl chloride, chloroform or its mixtures.

Methods—

A. By inhalation.

1. By a closed inhaler.

2. By an "open" method, itself varying in the hands of
different practitioners between a strictly open and drop system,
and by the use of a semi-open inhaler such as Allis', or a gauze
and lint covered mask closed in almost completely by an im-

pervious material, as in Dumont's ether mask and those commonly adopted on the Continent.

3. By the pharyngeal method.

B. Intratracheal insufflation.

C. Intravenous infusion by which saline shaken up with ether is allowed to infuse a vein.

D. Rectal and colonic etherisation by ether vapour, or saline or oil mixed with ether.

E. Intramuscular injections of ether.

F. By oral administration, *i.e.* drinking some mixture containing ether.

A. By Inhalation—1. The Use of Inhalers.

The main indications for the successful administration of this anæsthetic are, that the air inhaled should take up more and more ether vapour.   It cannot be too strongly insisted upon that, in spite of all theoretical reasoning to the contrary, asphyxial complications with ether should be carefully avoided.   It is best to commence the inhalation with a sufficiently diluted ether vapour so as not to excite laryngeal irritation ; the vapour should not escape into the room and impregnate the air breathed by the bystanders ; this can only be done by the use of one or other of the inhalers to be mentioned below.

Inhalers devised for the administration of ether by itself, or in succession to other anæsthetics, may be classed under the categories of (1) closed, (2) quasi-open.   In the first case the patient inhales ether from a bag closed from the air, so that whatever air enters does so through valves arranged with that object.   The best type is Clover's portable regulating inhaler. This inhaler has been modified and improved, but in principle it remains the same.   The form suggested by Dr. Probyn Williams is probably one of the best, as it combines a wide bore with great lightness and manageability (see p. 156).   (2) In the quasi-open type ether is poured upon a sponge or on an absorbent material which is surrounded by some more or less impervious substance ; if it is open at the top the patient is able to breathe through the sponge containing the ether.   The large mask designed by Dr. Julliard and modified by Prof. Dumont of Berne is the best of these.   Ether is sprinkled freely over the inner surface, the

external aspect being covered with oiled-silk. The Allis inhaler is a nearer approach to a truly " open " method and answers its purpose well. Ormsby's inhaler is a compromise between the two classes, as in its use the patient respires through the etherised sponge into a closed bag.

The Employment of Warmed Ether in Anæsthetising.

The adoption of some method whereby the ether introduced into the body of a patient can be sufficiently warmed is possible in most systems of etherisation, but is best achieved by some special apparatus, such as that devised by Dr. Shipway. This is described below. The importance of using warmed ether has only been recently explained and its value proved. We owe our present knowledge of this subject to the experiments and advocacy of Dr. Gwathmey,* and to the physiological and clinical observations of Dr. Pembrey and Dr. Shipway. The reader is referred to their original papers for details of their work.† They point out that under anæsthesia the vital processes are interfered with ; metabolism, nervous control over heat production, the due pulmonary ventilation, and corrective variations of the circulation are lessened, sometimes to a serious extent. The importance of this fact is evident when we remember the part which lowering of somatic temperature plays in producing that congeries of phenomena which constitutes shock. In sleep, although temperature falls through loss from the skin and emunctories, yet it is sufficiently counteracted by regulating heat mechanisms controlled by the central nervous system ; under anæsthesia the central nervous system is the first system to have its biochemical activities lessened or abolished. It is obvious, then, that this occurrence must be faced, and means adopted to maintain the body's heat. We have recognised for years that ether inhalation lowered the patient's temperature and have ascribed it to the removal of heat by the evaporation of ether during its elimination by the emunctories. The measures

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* Gwathmey, *Anæsthesia*, 1914, pp. 71 *et seq. et passim.*
† F. E. Shipway, *Lancet,* Jan. 8, 1916, p. 70 ; M. S. Pembrey and F. E. Shipway, *Proc. Roy. Soc. Med.*, vol. ix. 1916, No. 7 ; M. E. Pembrey, *Proc. Phys. Soc. Phys. Journ.*, vol. xvii. 1895, p. iv ; vol. xv. 1894, p. 401 ; same authors in Guy's Hospital Reports, vol. lxix. p. 223.

adopted to counteract this have been wrapping the patient's body in warm coverings and operating on him in a highly heated room. These are obviously less beneficial and much more detrimental than introducing the ether at a sufficiently warmed temperature, for this to some extent lessens the loss of heat due to the warming of the ether by the body during its introduction and elimination. Not only does the use of warmed vapours lessen the loss of heat by its abstraction during elimination, but it also stimulates the medulla and heart, and presumably increases heat production. This directly benefits the patient, while it obviates to some extent the necessity for overheating the operating-room. A theatre highly heated, with its steamy atmosphere, tends to produce fatigue, sweating, and irritability, all undesirable adjuncts to an operation. As warmed ether vapour causes less faucial irritation there is less liability to excessive secretion of saliva and mucus, so that the preliminary use of atropine becomes less a matter of necessity. Shipway has proved by his observations that ether so warmed minimises the fall of body temperature. Comparing patients who respired cold ether from an open mask inhaler (Schimmelbusch mask covered with gauze) with those who received ether warmed to a known temperature and conveyed into the respiration space covered by a similar mask, in the latter " the respective percentages of rise, fall, and no change, in rectal temperature were 35·8, 44·5, and 19·8, as against 16·6, 76·8, and 8·6 with [unwarmed] open ether." These findings agree with the physiological experiments conducted under test conditions, and so must be accepted as wholly reliable.

A further point of no small importance is that, as is indicated in various sections of this book, the after-effects and sequelæ of ether inhalation depend in no small measure upon the cooling of the body due to ether, so that, if such fall of body temperature is prevented, the deleterious after-effects of the anæsthetic are lessened or obviated. Less ether when warmed produces more rapid effects. By parity of reasoning, anæsthetic vapours other than ether should be warmed before administration. The vapours when warmed are more readily respired, so that the induction is easier and more rapid, and the maintenance of anæsthesia more uniform and easy, and, according to Bowlby and Wallace's observations made in France, after-vomiting is lessened.

Regulating Apparatus for the Administration of Warmed Anæsthetic Vapours.

Dr. Shipway's apparatus consists of an ether receptacle (E), a chloroform bottle (C), and a warming chamber (vacuum flask)
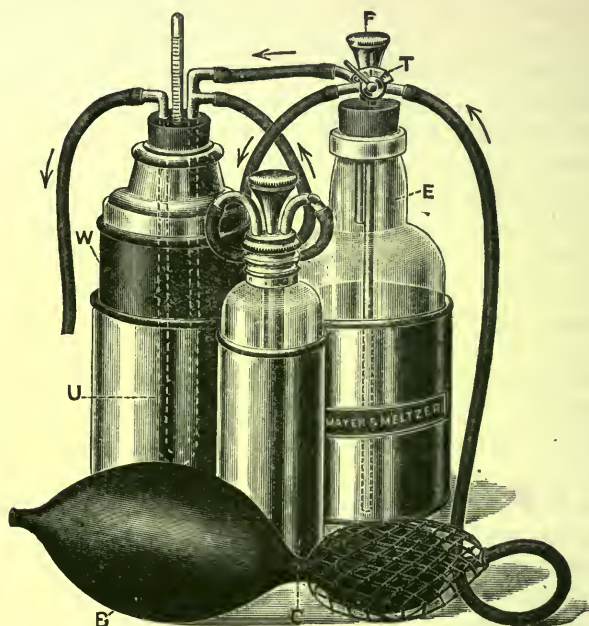
Fig. 26.—Dr. Shipway's regulating apparatus for the administration of warmed anæsthetic vapours.

B, a hand-bellows of large capacity ; E, an ether bottle ; C, a Junker chloroform bottle ; and W, a warming chamber (vacuum flask). E, C, and W are contained in metal stands connected together, that of C being detachable, and as well as that of E being of larger diameter than their respective bottles, so that they act as water-jackets to prevent excessive cooling of the anæsthetic. In the cork of E are : (1) An efferent tube ; (2) a filling funnel (F) ; and (3) a regulating tap (T), the long limb of which is plunged into the ether ; perforations at the end of this limb break up the air current and prevent splashing of the ether. To the proximal of the two short limbs of T is attached the hand-bellows ; the distal is connected by rubber tubing with the afferent tube of C. The efferent tubes of E and of C are connected by tubing to two branches on the afferent limb of U, which is a metal U-piece immersed in the warm water of W. The delivery tube of U carries 30 inches of rubber tubing.

(W). Hand-bellows (B) of large capacity are used for pumping the anæsthetic vapour from E or C, or from both at the same time in any proportion which is desired. This is controlled by the tap T. The strength of the vapour is determined by the force of the hand-squeeze of the bellows ; it can be increased by putting hot water (ether boils at 98° F.) into the water jacket ensheathing E. Six or eight ounces of ether are poured into E before commencing the administration. Where chloroform is not required, the container C can be disconnected and cut out of the circuit. In this event the distal limb of T is connected with the free branch of U. When this is done all the air or any part of it can be pumped through E. When in use the water jackets of E and C are filled with warm water.

Induction can be performed by any method, but if warmed ether or chloroform, or a mixture of the two, is desired, the efferent tube of the apparatus, which should not be attached to metal, since metal rapidly cools the vapour, is placed so as to deliver the vapour into the mask covering the patient's face. A pad of flannel or spongiopiline should be laid upon the face, as in the " open ether " method. The temperature of the vapour must be adjusted to the needs of the patient ; 90° F. is an average one, but 95° F. is better in cases of shock or vital depression.

Clover's small portable regulating ether inhaler (fig. 27) (see p. 152) consists, as reference to the figure indicates, of a dome-shaped ether receptacle pierced by a central shaft, into which are adapted (1) a tube bent at right angles, carrying the indiarubber bag into which the patient breathes, and (2) a metal tube which serves for the attachment of the face-piece, and has an indicator attached to it which records approximately the relative proportions of the ether and air respired. There is a tube with stopcock for inflating the air-cushion which rims the face-piece and helps it to fit the face accurately.

The ether reservoir, and water chamber which surrounds it and maintains it at the desired temperature for evaporation, rotate upon the metal tube shown in the diagram with the figure " 2 " upon it. This fits accurately in the mount of the face-piece, and the projecting indicator is received into a slot in the mount. The instrument is constructed so that no liquid ether can escape in whatever position the inhaler is placed.

1. Method of Using Ether Inhalers.

"**Clover**" **type.**—The patient is placed in the dorsal position and his eyes properly protected. A face-piece of an appropriate size having been selected, and two ounces of ether placed in the reservoir, lasting approximately half an hour, the air-bag is removed and the indicator turned to O. The patient is then directed to inspire freely, and the face-piece applied gently but firmly, uniform pressure is well borne, while hard pressure, if unequally distributed, will not be tolerated. When the patient
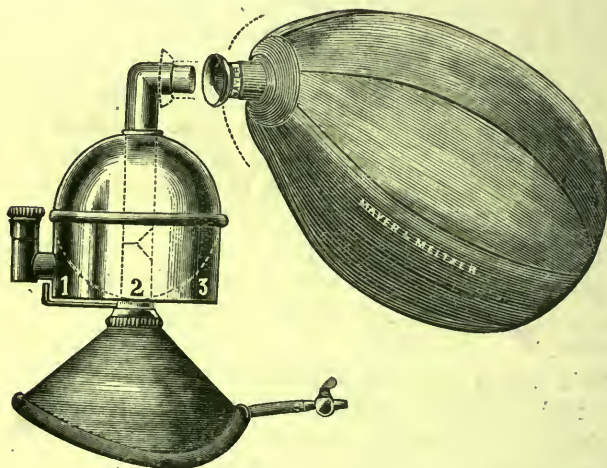
FIG. 27.—Clover's small portable regulating ether inhaler.

has taken two or three deep breaths, the air-bag is filled by placing it in position as the patient expires the air from his lungs. The ether reservoir is next turned so that the indicator points to the figure "1," and the patient then breathes about one-fourth ether vapour and three-fourths air. A few breaths of such a dilution of ether will accustom the larynx to the irritating vapour, and so coughing, spasm, and the wretched feeling of suffocation which ensues upon presenting a strong ether atmosphere at the commencement of an inhalation are avoided. This tolerance achieved, the ether reservoir is rotated till the indicator points to "2," and the patient then inhales, roughly speaking, half ether vapour and half air. If this

strength of vapour does not distress him, the indicator, by further rotation of the ether chamber, can, after a few seconds, be made to point to " 3 " (one-fourth part air, three parts ether) and then to F (full ether).

The variation in size of the pupils during ether narcosis is an uncertain guide. They are not uniformly influenced by the anæsthetic as in the case of chloroform, and so have no common ground of comparison. When full anæsthesia is established the pupillary reaction to light will be less active and the size of the pupils will remain fairly constant, tending to dilate when the anæsthetic is pressed. Excessive doses produce a slowly reacting pupil and wide dilatation. The same result follows when much shock occurs with loss of blood and the anæsthetic has been given freely. Although in many instances increasing the depth of narcosis dilates the pupil and renders the light reaction sluggish, while lessening the degree of narcosis causes the pupils to contract slightly, these phenomena are not absolutely constant ; some pupils, especially in old persons, remain contracted, while others are moderately dilated and show little change. In moderate degrees of narcosis the pupils will be seen to change in size synchronously with respiration. It is never well to push the ether to a degree in which light reflex is almost abolished. The younger the eye the more active are the pupillary reactions. In testing all eye reactions it is important to avoid frequent and rough handling of the conjunctivæ and to compare the two eyes, since one eye rapidly loses its reactions unless allowed to be quiescent.

With the assistance of Mr. Upcott Gill, who was my chloroform clerk, I examined a large number of patients, and the statements made above represent the conclusions at which I arrived. It may be added that as a rule the advent of cyanosis was associated with some pupillary dilatation. Blue and grey eyes are more sensitive to light than are brown, and they show exhaustion more speedily unless protected from strong light.

The patient will, in from ninety seconds to two and a half minutes, be completely unconscious and ready for operation. The muscles are rigid at first but subsequently grow flaccid ; as a rule consciousness is lost as soon as this rigidity is present, but the profound narcosis required for many operations only super-venes with muscular relaxation. Any cyanosis or respiratory embarrassment will prolong the period of rigidity. I have re-

peatedly produced relaxation at once by allowing the patient to inhale oxygen. Some persons require more ether to render them insensible, and those who persistently resist taking the anæsthetic by holding their breath, or by taking the shallowest breath consistent with life, will delay the onset of unconsciousness much longer. These persons also, since they voluntarily semi-asphyxiate themselves by repressing respiratory movements, suffer great additional discomfort from the feeling thus brought about. This recalcitrancy is usually due to the administrator having employed a too concentrated vapour to the sensitive mucous membrane of the upper air-passages.

As soon as complete anæsthesia is thoroughly established, that is, when the conjunctival reflex is abolished, the indicator may be brought back to " 2 " by turning the ether reservoir round and keeping it there until the operation is over. It may be necessary in warm weather, and in the case of prolonged operations, to renew the ether in the receiver. This is easily done by removing the inhaler from the patient's face, loosening the stopper, and pouring in a further supply. Care must be taken, however, to lessen the strength of the ether on reapplying the inhaler lest some spasm be induced.

The patient will, during a protracted operation, require the inhaler to be lifted off his face every sixth breath or so, in order that he may take a few inspirations of air. The necessity for this will be readily recognised by any cyanosis apparent in the face or ears, and by the character of the respirations and of the pulse. It should be carefully borne in mind that the amount of an anæsthetic required to produce anæsthesia is much greater than is needed to maintain that condition. Also the degree of narcosis must be varied in correspondence with the region of the body upon which operative measures are being pursued. For operations upon the abdomen, the genitals, the rectum, or the perineum, a deep narcosis is necessary, and must be maintained throughout the operation, otherwise movement and vomiting may result. To test the degree of narcosis, although the size of the pupil is an unreliable guide, it may be noted from time to time to see whether the light reflex remains keen and the corneal reflex is returning. In deep narcosis, that is short of overdosage, the lid reflex is quite abolished, the pupils may be semi-dilated, the ocular movements sluggish and the light reflex slow. Fixation of the eyeball seldom, if ever, occurs in ether

narcosis unless the ether is administered with oxygen, as in that case the depth of the narcosis may be very profound. The respiration is often hurried in light, but slower and more shallow in deep narcosis, while the breathing is gasping and some stertor may be heard. The ruddiness of early etherisation gives place to pallor with slight duskiness after prolonged or profound etherisation. The advent of returning consciousness is commonly shown by the patient's efforts at swallowing, the initial act of the physiological mechanism of vomiting, by return of conjunctival reflex and by alteration in respiratory rhythm.
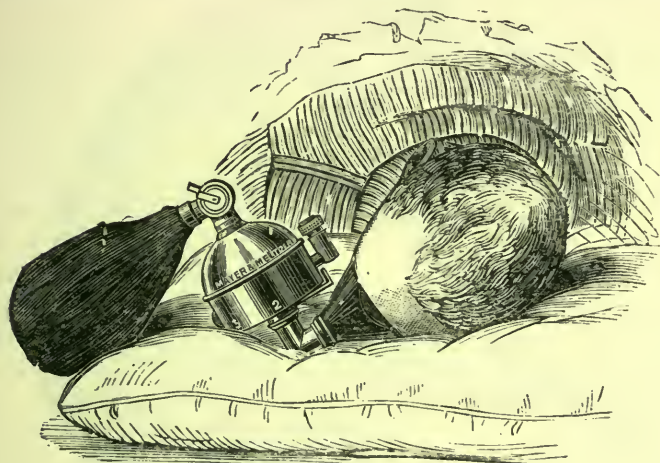
FIG. 28.—Sheppard's angular adjuster.

Frequently also pallor, with sudden pupillary dilatation, may occur. In all cases it must be remembered that the dilatation of the pupils, variations in respiration and circulation, may be reflex, and must not be mistaken for ether effects. It is this fact which convinces me that students should avoid consulting the pupil in ether narcosis until they have acquired a thorough mastery of the cycle of ether narcosis as a whole. Although obvious, it may be pointed out, that in cases in which a preliminary hypodermic injection of atropine has been made, the pupillary phenomena are so masked as to be wholly unreliable.

When it becomes necessary to anæsthetise the patient in the prone or semiprone posture, a useful addition to the Clover's

regulating ether inhaler is the angular adjuster figured above (see fig. 28).

Mr. Clover intended his small portable inhaler for the administration of ether alone, but it has been adapted for the exhibition of that vapour in conjunction with nitrous oxide gas, and Mr. Clover himself, writing in 1877, says, "by connecting the bag with a supply of nitrous oxide it forms a tolerably efficient substitute for the gas and ether inhaler" (see p. 173). Thus, by attaching a stopcock in the metal bent piece to which the

FIG. 29.—Probyn Williams' ether inhaler (wide bore).

bag is attached, gas can readily be admitted into it by a long indiarubber tube coming directly from the gas bottle, or the same end is achieved by having a vulcanite tube and stopcock inserted at the distal end of the rubber bag and connecting this with the tube to the gas cylinder.

It has been urged, as an objection to Clover's regulating inhaler, that the lumen of the tube through which the patient has to inspire is too small to permit of unembarrassed respiration. As a result, it is alleged, the patient tends to become cyanosed and suffers from feelings of impending suffocation.* The late Sir

* This question is fully discussed by the late Sir F. Hewitt, *Lancet*, March 30, 1901, and his own wide-bored inhaler is there described.

Frederic Hewitt,* who has carefully considered this question, attached great importance to the presence of a wide bore in the inhaler, and his apparatus provides such an increased size of air-way. Whether this is not a theoretical rather than an actual objection is, I think, open to question. The patient obtains his ether and air from the face-piece, and provided the tube to the ether-supply and bag is not less than the diameter of the trachea, it is difficult to understand how, when the content of the face-piece is gradually emptied by inspiration, there should be any impediment to breathing such as would cause *besoin de respirer*. When a small bag is used there is no doubt that such a result may occur, but in that case it is the size of the bag rather than the diameter of the bore which is at fault. Clover, when scheming his inhaler, considered this question, and had the bore made at least as large as the lumen of the trachea in order to prevent any difficulty in breathing.

Ormsby's inhaler.—It consists (fig. 30) of a zinc face-piece with cushioned rim capable of being inflated through a small tube guarded with a stopcock. The face-piece is provided with a valve, which can be opened at the pleasure of the administrator ; at the top of the face-piece is a cone-shaped wire cage, covered externally with red rubber and leading into a rubber bag covered by a loose net which prevents its undue expansion. In the wire cage a sponge is placed, and upon this half an ounce of ether is poured.

In fig. 31 is shown Mr. Carter Braine's modification of Ormsby's inhaler by which a succession, A.C.E., ether, or chloroform, can be given. It is constructed throughout of metal, nickel-plated, all parts are easily accessible, and can be rendered aseptic by boiling. The air-valve is a free one and is numbered with figures, as on Clover's inhaler. The cage, being rigid and made of open-work, is incompressible, permits of free respiration, and cannot become constricted with use. The respiratory bag is 12 inches in diameter, so that the net is not needed. The cage bearing the sponge and respiratory bag fixes on the face-piece with a bayonet catch. There is an extra dome constructed of metal and freely perforated with air-holes at its extremity ; this also fits on to the face-piece with a bayonet catch and takes the place of the other dome. This attachment is very useful for the administration of the A.C.E. mixture or for ether when

* " Anæsthetics and their Administration," 1912, pp. 348 *et seq.*

plenty of fresh air is necessary, as in the case of young children and of the very feeble. The administration can be begun with the A.C.E. mixture, and then the A.C.E. dome detached when required, the other dome applied in its place, and the administration continued with ether. Should it be desirable to change the anæsthetic to chloroform, the tube from a Junker's inhaler can be applied to the projecting tube of the A.C.E. dome, and the chloroform apparatus is thus completed. Should the entry of air be too free, then some of the holes at the extremity of the
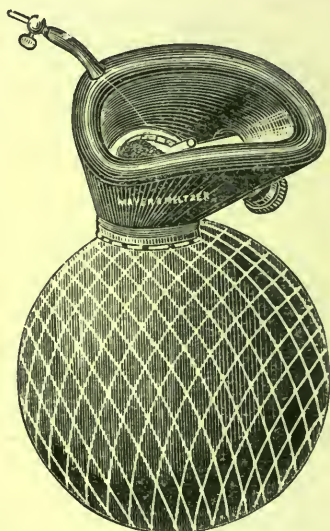
FIG. 30.—Ormsby's ether inhaler.

dome can be occluded with the hand or by packing with some cotton-wool.*

METHOD OF USING ORMSBY'S INHALER.—The sponge is wrung out in warm water before use, but if, as Carter Braine suggests, an open sponge be loosely packed into the cage and only small quantities of ether are poured on at a time, this is unnecessary. The valve should be open at first and gradually closed as the larynx grows accustomed to the ether vapour, and the inhaler should be held lightly over the face and only fitted closely as toleration becomes established. When fresh ether is required, it can be either poured through the tube designed for this purpose,

* See *Lancet*, December 3, 1898, p. 1,488.

or, as I think is preferable, thrown directly upon the sponge by removing the inhaler from the patient's face and inverting it. Care must be taken that there is no excess of the anæsthetic, which may trickle over the face. It is well to have a second sponge in readiness in case the first one freezes. The second one can be conveniently kept in warm water within reach. Unless care is taken to give the ether gradually by leaving the valve freely open at first and by putting on only small quantities of ether (half an ounce or less) at a time, the patient experiences great distress from a feeling of suffocation. This and the lia-

FIG. 31.—Carter Braine's modified Ormsby's inhaler, the " extra dome " and the air-pad of the face-piece.

bility of the sponge to freeze are the two great objections to this inhaler, but, as the description above shows, these can to some extent be overcome by care and expertness. Another objection to it lies in the fact that, a gradual increase or lessening of the quantity of ether given, cannot be so well effected as in the case of Clover's inhaler.

Rendle's mask (fig. 32) is a convenient pattern. It is made of leather, and contains a thick flannel cap which is allowed to extend beyond the lower edge and be folded back so as to rest upon the face when the mask is applied. At its summit a sponge is placed, upon which ether is dropped in small quantities, a

drachm or two from time to time. Subsequently half an ounce may be used as required. A free air-way is obtained by perforations at the summit of the cone. If the sponge freezes it must be replaced by another which should be ready at hand as in the case of the Ormsby's inhaler. This inhaler is also made of celluloid (Silk). In the use of this mask excess of ether may soak into the flannel and drain over the patient's face. The cone is at first held an inch or so away from the face, and gradually approximated. It is lifted to renew the ether or to prevent cyanosis.

Semi-open inhalers.—The simplest form is a towel or piece of millboard rolled in the shape of a cone with a sponge placed at its summit. Ether is poured upon this and renewed from

FIG. 32.—Rendle's mask and flannel cap in cone.

time to time. This plan is not satisfactory, and unless in exceptional cases, when there is great asthenia or collapse, it is difficult to produce complete anæsthesia with it. Such make-shift inhalers are now usually replaced by the use of gauze on a wire mask (see below).

Allis' inhaler.—This is, I think, the best " semi-open " ether inhaler ; for while it can be used for chloroform, the A.C.E. or other mixture, it is always available when it is desirable to give ether largely diluted with air. It possesses the disadvantage common to all instruments of its class, that much ether is wasted, and becomes diffused through the room to the discomfort of the operator and his assistants. It consists, as can be seen from the woodcut, of a metal frame so arranged that a flannel or domett bandage can be stretched across and across. The outside is covered with a leather case, which being prolonged below the

metal serves as a well-adjusting face-piece. Fresh additions of the anæsthetic are dropped from time to time upon the bandage from above. This may be done from a drop bottle, or the inhaler may be inverted and a few drachms poured in from below. Its use needs no full description. At first a comparatively weak vapour strength should be employed ; subsequently the requisite concentration may be rapidly obtained by pouring on more ether.
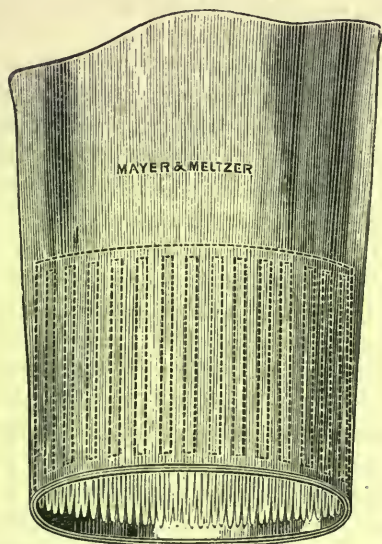
FIG. 33.—Allis' ether inhaler.
(The inhaler is represented upside down in the figure.)

The bandage must be removed and the inhaler carefully cleansed after use and a fresh bandage applied. These inhalers can be made up of whatever size is required.

The Administration of Ether by Itself.

The effects of ether inhalation will vary considerably according as the patient is narcotised rapidly or slowly. Slow etherisation possesses no advantages under ordinary circumstances, and is indeed positively harmful by prolonging the stage of delirious excitement. In conditions of extreme shock, or asthenia after great loss of blood or ensuing upon a prolonged illness, it may be necessary to proceed with extreme caution and to employ

small quantities of the anæsthetic, but this does not affect the general principle enunciated above.

The inhalation.—The actual administration is nowadays seldom performed by the use of ether alone, but to avoid confusing the reader, the following account assumes that ether is being given by itself. It is done by the use of an inhaler or by an open method, but before considering these methods in detail it will be well to present a general account of the phenomena met with during the period of induction.

The patient being placed in the supine position and his clothing loosened, his mouth is examined for artificial teeth or an obturator, and if such are present they are to be taken out and ether administered by one of the above methods. Although the supine position is best, yet for operations for the removal of the teeth, or upon the post-nasal space, the patient may be allowed to be propped in a sitting posture, or even be seated in a chair.

When the patient first breathes ether vapour, he catches his breath, may cough and resist the ingress of the vapour. The resistance will be in proportion to the strength of the vapour used. A few inspirations will render him dazed, the face will flush, the eyes grow suffused, and the breathing will become rapid. The pulse in this stage is full, softer than natural, and accelerated. Although stupefied, the patient can still perform certain voluntary acts, *e.g.* putting out the tongue if loudly desired to do so. The feeling of suffocation which was at first experienced now gives place to one of exhilaration, the dyspnœa disappears, and the respirations are full and deep. Formication and tingling are felt in the hands and feet. The pupils usually contract in this stage. The exhilaration, however, soon passes into a condition of delirious excitement. Bert denied that true excitement occurs, believing that progressive loss of muscular power always supervened. The disorderly movements commonly put down to excitement of delirium are, he thought, to be explained as *une sorte d'anarchie cérébrale*, the guiding centres being in abeyance. In whatever way we regard these movements, they certainly appear to be the result of temporary delusions. Thus, military men may, in this stage of etherisation, shout words of command ; while those inclined to pugilism may attempt to box with the bystanders. The stage of excitement varies within wide limits ; if the administration is well managed and the strength of vapour gradually increased without exciting

asphyxial complications, it is usually short and slight. In the case of alcoholics and persons of powerful physique it is commonly pronounced and the movements violent, but such manifestations are the exception rather than the rule. The respirations and heart's action are considerably accelerated; the skin grows moist, in some instances profuse sweating occurs, and the face becomes dusky. Soon a period of quiet follows, and it should be the aim of skilled etherisation to curtail as much as possible the stage of excitement. In the succeeding quietude the limbs stiffen, the muscles are strongly contracted and firmly set, the whole body becoming rigid. Breathing may be hampered by the rigidity of the thoracic muscles, and needs careful watching at this time. Should the respirations stop, it will be necessary to lift the inhaler and firmly compress the chest with the hand two or three times and so encourage respiration. The pupils now dilate and the skin becomes bedewed with perspiration, while a **roseolous rash** appears in patches about the neck and chest. These patches coalesce. In several hundred cases examined by me it was generally present in some degree, although often so transient and slight as to be easily overlooked. The pulse now resumes its normal rate, and although soft, remains regular and somewhat more forcible than before inhaling the anæsthetic. The blood-pressure is raised, but falls nearly to the normal when anæsthesia is fully established. Then ensues the stage of muscular relaxation. The patient lies absolutely insensible to all external impressions, with his muscles perfectly flaccid. The **lid reflex** is **lost,** and the eyes move slowly from side to side. The breathing slows, although it keeps quicker than normal, and is much more shallow. At this time anæsthesia is complete, and operative measures may proceed.

The depth of narcosis varies according to the amount of the anæsthetic given. For brief operations not involving a very sensitive area a light narcosis is to be aimed at, and in every case as little of the anæsthetic should be given as is consistent with the necessities of the operation. It must always be borne in mind that the severity of the after-effects is dependent upon the amount of the anæsthetic inhaled, and the toleration of the patient for the anæsthetic. When once true anæsthesia is obtained the patient requires comparatively little ether to keep him insensitive.

The recovery.—The time which elapses between the moment

when the anæsthetic is withdrawn from the patient, and that when he is conscious and has resumed control of his actions, varies in length in different cases. Generally speaking, the duration of this period of " recovery " is longer directly in proportion to the amount of the anæsthetic taken, and inversely to the physique of the patient. Some persons simply sleep off the effects of the ether, are often a little sick and vomit some mucus or clear fluid smelling of ether. Others become excited, going through a period of excitement similar to that which many persons experience in " going under " ether. A few, especially the neurotic, appear almost maniacal for a time. The maudlin and the jocular phases of emotion may reveal themselves and call for only passing mention. Others, especially when a severe operation has necessitated the inhalation of a large quantity of the anæsthetic, reveal a profound stage of collapse, are cold, motionless, with hurried weak breathing and feeble pulse. This is often the result not only of surgical shock, but of nerve-centre exhaustion consequent upon over- and excessive ether stimulation. Certain persons commence to vomit immediately the etherisation has ceased, and continue to do so for hours with more or less frequency. All the above conditions may be slight and transient, or may need careful and suitable therapeutic treatment. No patient should be left unattended after taking ether, lest through a malposition assumed in a semi-conscious movement his respiration becomes impeded and suffocation ensues. Another danger from vomiting during recovery is that the vomitus may enter the air-passages and choke the patient. Several deaths have ensued from syncope occurring in unattended patients who have sat up suddenly during recovery.

A more insidious danger during this period is chilling of the patient. Often he is removed from a heated operating-theatre, or room, and carried into an improperly warmed ward or bedroom, with the result that bronchitis, or even broncho-pneumonia, supervenes, and this is inaccurately ascribed solely to the effects of the ether or a " dirty inhaler." In all cases the patient should be carefully wrapped in blankets, hot-water bottles placed in suitable positions, care being taken that their heated surfaces cannot touch and burn the skin—a not infrequent danger—while he should be so arranged that the head lies with the face turned to the side. An attendant should be close at hand to restrain undue movements, uncovering of the body, and to help in the

event of sickness. Special treatment required for more grave complications and after-effects are considered below. Comparing the use of Clover's inhalers with an open method, a great point in favour of the latter is urged, that the bags and face-pieces of closed inhalers may become septic and a source of infection. However, there is less in such an allegation than would appear at first sight. If reasonable care is taken and cleanliness is insisted upon, all dust or dirt is easily removed, while the rubber can be washed in an antiseptic lotion after use and again immediately before the next case. Further, the vapour of ether, as has been shown by Sternberg and others, is itself a powerful bacteriocide. The modification of Clover's larger inhaler which Messrs. Mayer and Phelps made for me some years ago permits of complete cleansing, as the bag is detachable and the metal parts can be boiled.

2. The Open Method of Etherisation.

Open methods of producing anæsthesia by ether.—The phrase " open ether administration " covers a number of procedures which are not strictly " open," as masks are sometimes almost covered with impervious material and in some cases inhalers even are adopted.

In every case atropine, gr. $\frac{1}{100}$, or some suitable dose should be injected one hour before the inhalation. A mask * such as that used by Mr. Mayo, or of the Skinner or Schimmelbusch types, is sterilised, and twelve to eighteen plies of gauze are laid so that they extend on each side and below the chin, while a single thickness of lint is placed over them and the whole is fixed in position by the ring or hinged attachment. A small hole to serve as a window is cut in the lint on the side of the mask which will remain uppermost throughout the narcosis. The head should always be turned to the side away from the seat of operation. The ether-supply can be obtained by a dropper such as the figured one below (fig. 34) or an ordinary bottle can be fitted with a cork in which two slots have been cut. I have my ether placed in ℥iv. bottles which, once opened, are never kept for a subsequent anæsthetisation. In one of these slots a

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* The plan suggested is that which the author, after many trials of various systems, has elaborated and now usually employs, although Dr. Ferguson's method described below possesses undeniable advantages.

few strands of wick thread folded together are passed so that the wick falls to the bottom of the bottle and a free end hangs for one-quarter inch out of one of the slots in the cork. The other slot admits air into the bottle. The cork must not be pressed in so tightly that air cannot enter freely, or the ether will not readily drop. The patient's eyes are protected by a pad of lint, and as soon as he is sufficiently dazed by the ether a few drops of pure castor-oil are instilled into them so as to prevent the ether vapour setting up conjunctivitis. The cheeks

FIG. 34.—Jackson's ether dropper.

and chin can be protected if necessary from ether irritation by vaseline, oiled-silk, or a folded towel, but unless the ether is poured on too rapidly this precaution is seldom required. A ring * made out of spongiopiline with an aperture taking the mouth and nose answers very well as a protection against ether irritation and also prevents the possible bruising of the face by the metal mask. Gwathmey speaks highly of the use of oil of bitter orange peel [25 per cent. of oil of bitter orange peel U.S.A. in 75 per cent.

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* I see that the late Sir Frederic Hewitt adopted a similar plan, and used a gauze pad, but this last is open to the objection that it is readily permeable to any ether leaking upon it.—" Anæsthetics," 4th ed., p. 339.

of alcohol U.S.A.] as a preliminary to giving ether by an open
method. He drops it on the mask before the ether, and then
simultaneously with the anæsthetic.*

The mask, being placed in the appropriate position, is held by
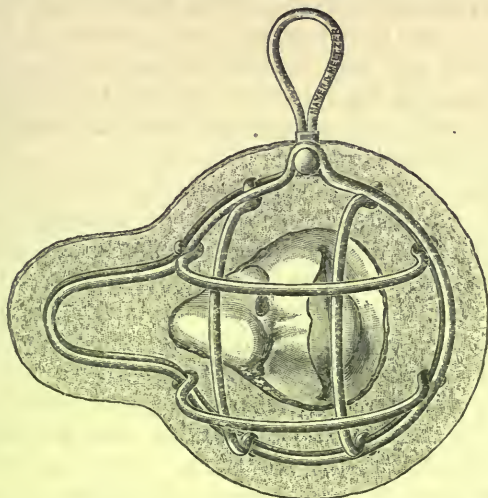
FIG. 35.—Showing spongiopiline ring on the face with Mayo's mask
without gauze resting *in situ.*
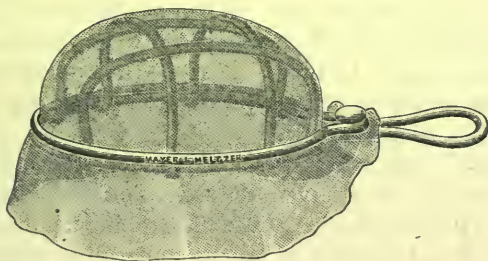
FIG. 36.—Side view of Mayo's mask.

Shows Mayo's mask with single layer of gauze spread over it ; in practice twelve to fifteen
layers are so placed.

the left hand which also supports the mandible, while the right
hand holds the drop bottle. This is inclined to such an angle
that the ether falls drop by drop on to the gauze left exposed

* "Anæsthesia," p. 92. Woolsey of Brooklyn has devised a plan
(*op. cit.*, p. 93) whereby the oil of orange can be employed in closed ether
methods.

by the window cut in the lint. At first the drops should fall at fairly long intervals, but as soon as the patient becomes accustomed to the vapour their frequency can be increased. At no time should the lint become soaked, as this prevents evaporation except perhaps in very hot weather, while it also checks the escape of the patient's expirations, so causing him inconvenience, and may occasion cyanosis. The duration of induction is about ten minutes, but weakly persons go under more rapidly, while vigorous, muscular individuals often require longer time for the induction.

Nervous people by holding their breath and taking very shallow respirations can delay induction. This is usually due to an unwise pushing of the anæsthetic in the initial stage, and is corrected by lessening the rate of dropping and by pushing forward the mandible as soon as an inspiration has commenced, and so deepening and prolonging the intake of air and vapour. Children as well as nervous persons often give trouble in this way, and it may be requisite to give a few inspirations of the A.C. mixture **on another mask having only a single layer of lint in order to start the induction.** Under no circumstances should chloroform or its mixtures be dropped on the ether mask with its many folds of gauze, otherwise a high concentration of vapour will remain in the mask, and as breathing deepens an excessive dose will be inspired. When morphine has been given before the inhalation the breathing is apt to be slow and shallow, and similar measures to those mentioned above are commonly called for to save a needless expenditure of time and to obtain a satisfactorily deep narcosis.

Usually there is but little struggling or excitement, and, provided atropine has been given, no salivation or undue secretion of mucus. If this preliminary use of atropine has been omitted there is often a free flow of mucus and saliva which hinders quiet breathing. Cyanosis is absent unless some interference with respiration has occurred, although an attempt at a rapid induction by pouring on the ether instead of dropping it may set up cough, spasm, breath-holding with cyanosis. Prolonged narcosis when ether has been given freely will in the later development of the period of maintenance also cause cyanosis, and this, at the period mentioned, is usually a sign of overdosage calling for removal of the mask and free ventilation of the lungs with air, or better with oxygen. Edentulous patients with

muscular, pendulous lips so commonly found associated with the loss of teeth and shrinking of the alveolar processes, may give trouble as soon as consciousness is lost. The lips are sucked in during inspiration, forming a valve which, while it permits expiration, allows little air or ether vapour to enter. The use of a dental prop between the gums in the front of the mouth or a gag placed at the side will remedy this and allow the requisite depth of narcosis to be obtained. Some anæsthetists use an artificial airway, *i.e.* a tube which is grasped by the lips and passes over the tongue to the isthmus faucium, ensuring a free air-passage. These contrivances are apt to slip about in the slimy buccal mucus and get out of position, and so need careful watching. If the covering of the mask becomes too wet, the supply of ether should be withheld and a towel covered by the warm hands may be placed for a minute or so over the wetted area until evaporation has taken place. This if properly done will not interfere with respiration. However, should cyanosis or even duskiness coexist with an excessive ether-supply it is best to lift the mask until the normal colour has returned and then proceed more cautiously by the dropping method. It has been estimated that the concentration of the ether vapour given from a closed inhaler is about thirty per cent., whereas that presented by the open mask is never more than twelve per cent., and is usually less than this, *viz.* about six per cent. In an open ether method the material used for the evaporating surface is a matter of importance. When " spread " is rapid and the use of a fine meshed material allows rapid air movement through the mask coverings evaporation is accelerated. This difference in concentration of the ether atmosphere inhaled, accounts for the lighter character of the narcosis under an open method, but since the breathing appears to be more free and lung ventilation more ample during its use, the net result is, that although less ether enters the air-passages in a given time, yet its entrance being more easily obtained, a very large amount will eventually gain access to the circulation and a sufficient depth of narcosis will be achieved. To avoid the unnecessary waste of time during induction with the associated discomfort to the patient the open method may be supplemented, and I think usefully, by the employment of some preliminary system of anæsthetisation which accelerates the induction and assists to deepen the initial narcosis, *e.g.* the nitrous

oxide and ether sequence. This last is an important matter
when the operation is one requiring complete relaxation of the
muscles about the area of operation and absolute immobilisation
of the patient with suppression of such reflexes as disappear only
during deep narcosis. It must, however, be remembered that
many visceral reflexes, such as those connected with respiration
and even those associated with skin areas of great sensitiveness,
cannot be abrogated unless the life of the patient is to be placed
in jeopardy. The usual depth of narcosis obtained by an open
ether method is one consistent with " maintenance " as opposed
to " induction," and hence the methods to be specified are useful
if not essential for the best results to be gained when the open
method is pursued. The induction when giving open ether
throughout and without the preliminary use of alkaloids, being
long and involving a continued period of light narcosis, is often
complicated by vomiting and the patient is apt to doze, so that
precautions taken to prevent the former annoyance, and the
jaw movements mentioned above to obviate the latter, are
commonly required.

For deepening the narcosis the preliminary use of scopolamine,
morphine, and atropine is excellent, although these drugs also
tend to make the patient breathe shallowly, restricting pulmonary
ventilation, hence it is necessary to take measures to ensure free
breathing. The use of these drugs materially lessens the quantity
of ether requisite for obtaining an even and profound anæsthesia;
as their action persists for some hours it is essential that over-
dosing with ether be avoided, with its result, more or less pro-
longed and deleterious post-operative anæsthetic effects. The
patient must be carefully watched until he has completely come
out of the deep stupor sometimes caused by these drugs. To
hasten induction various methods, considered in detail in other
sections, may be adopted. Thus nitrous oxide or ethyl chloride
followed by ether from an inhaler, or chloroform or one of its
mixtures, e.g. the A.C., the A.C.E. (pp. 173 and 178), may be em-
ployed to commence induction. Although giving chloroform
during the induction period is obviously open to criticism, yet
when a regulating inhaler is used the danger is minimised if
not obviated. Indeed, after morphine and scopolamine, it is
wise to adopt chloroform or a chloroform mixture as an introducer
to the ether to obviate the rousing effect of the latter anæsthetic
upon the patient bemused by the drugs.

FERGUSON'S INHALER FOR THE ADMINISTRATION OF ETHER BY THE OPEN DROP METHOD.*

The following method, due to Dr. Ferguson, of East Orange, New Jersey, U.S.A., who was one of the first to introduce and systematise the open ether method, is one of the best.

The apparatus consists of a wire frame, fig. 37, so constructed that over the convex portion, A (figs. 37 and 40), several layers of surgical gauze may be stretched and held taut in position by the flexible wire E (fig. 37), as illustrated in fig. 40. The whole is covered with a Canton flannel hood (fig. 39), so made that it can be drawn up closely against the flexible face wire,
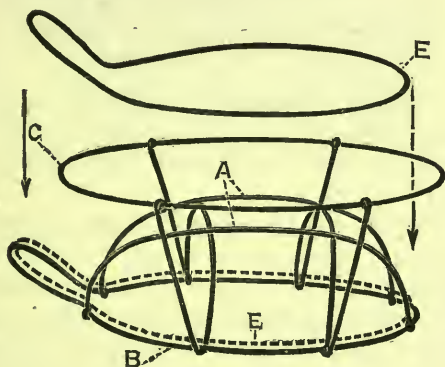
FIG. 37.—Ferguson's mask with parts separate.

B (figs. 37 and 40), and gathered on top so as to leave an opening, G (figs. 39 and 40), three-fourths of an inch or an inch in diameter. In this way two chambers, K and M (fig. 40), are formed, in the upper of which the ether and air become mingled while the patient inhales the mixture from the lower one.

Directions for Use.—Remove the flexible retaining wire, E (fig. 37), and then *fit the wire frame*, A, B, C, E, *accurately to the face of the patient*, so that no air can enter between the inhaler and the face. As the face wire, B, and the convex portion, A, are made of very flexible wire, the fitting can be easily done by

* See Dr. Ferguson's article on the inhaler in *Journal American Medical Association*, Dec. 30, 1905. The description in the text is given mainly in Dr. Ferguson's own words.

bending the wire between the fingers. Further, if the face be long and narrow, the inhaler may be lengthened by pulling it out in the line of its major axis. If the face be broad the instrument may be widened by pulling it out in the line of its minor axis. After the frame has been thus fitted, place over
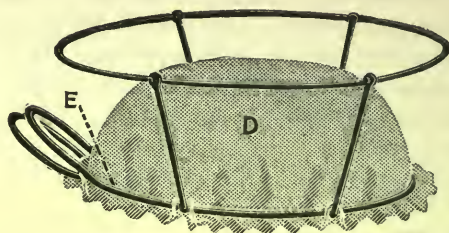
FIG. 38.—Mask with gauze in position.

the convex portion, A, several layers of surgical gauze of such size as to completely cover the convex portion A. Then insert the flexible retaining wire E, and press it home, thereby stretching and retaining the gauze.

The number of layers of gauze to be used is dependent upon the size of the mesh of the gauze, usually ten layers.

After the gauze has been adjusted, cover the whole frame with the Canton flannel hood. This is done by first inserting the wire loop *which comes over the nose* through the small opening
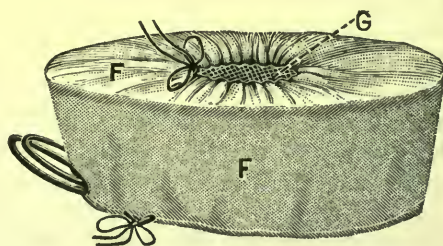
FIG. 39.—Complete with " Canton " flannel hood.

made for it, and then drawing the rest of the hood over the frame. The lower part of the hood should be made to fit closely and accurately around the face wire, B, without allowing it to impinge upon the large opening of the inhaler, which comes next to the face. The inhaler will thus fit closely to the face, and,

at the same time, the edge of the bag will form a cushion which will prevent any harsh contact of the wire with the face.

The apparatus, now ready for use, is laid gently over the face of the patient. If properly fitted, no air will pass between the face of the patient and the inhaler, but all air will go in and out through the opening, G (figs. 39 and 40). Subsequent proceedings, dropping on of ether, and so on, are conducted on the same lines as those given above, p. 165.

The use of this mask saves much ether and fits the patient's face far better than such extemporised masks as those made by using a Skinner or Schimmelbusch type.
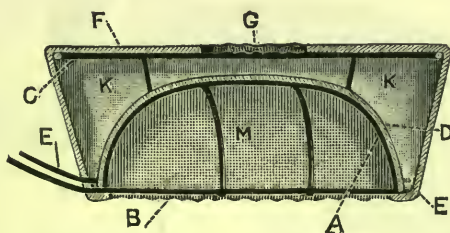
FIG. 40.—Showing section of mask after final adjustment.

SUCCESSIONS AND MIXTURES OF ANÆSTHETICS.

ETHER IN SUCCESSION TO NITROUS OXIDE.

Clover's nitrous oxide and ether method.—This plan, which at the time of its first adoption revolutionised the practice of ether narcosis and rendered ether at once a safe and satisfactory anæsthetic, is based upon the principle that the patient is able without discomfort to inhale nitrous oxide, and when unconscious, ether vapour in increasing strength is mixed with the gas, and finally ether vapour inhaled by itself. In this way there is no break in the continuity of the narcosis and no sudden transition, *i.e.* nitrous oxide gas first, then this anæsthetic mixed with ether vapour, and finally ether vapour alone.

Clover's large gas and ether inhaler.—The present form is the same in principle as that designed by Mr. Clover, although it has been modified and improved. It is shown in the diagrams given below. The nitrous oxide gas supply is derived from steel cylinders (fig. 41) placed horizontally, and the gas traverses

an indiarubber tube to the ether chamber. This is shown in fig. 41. The apparatus is so arranged that gas can be given alone or with ether. By turning the tap on the summit of the ether chamber the gas passes directly into the receiver containing ether, and having traversed it and passed over the surface of the ether, escapes into the face-piece along a tube which traverses the Cattlin's bag shown in the figure by dotted lines. The amount of admixture of gas and ether is regulated by a tap placed on the metal connexion between the rubber gas-bag and
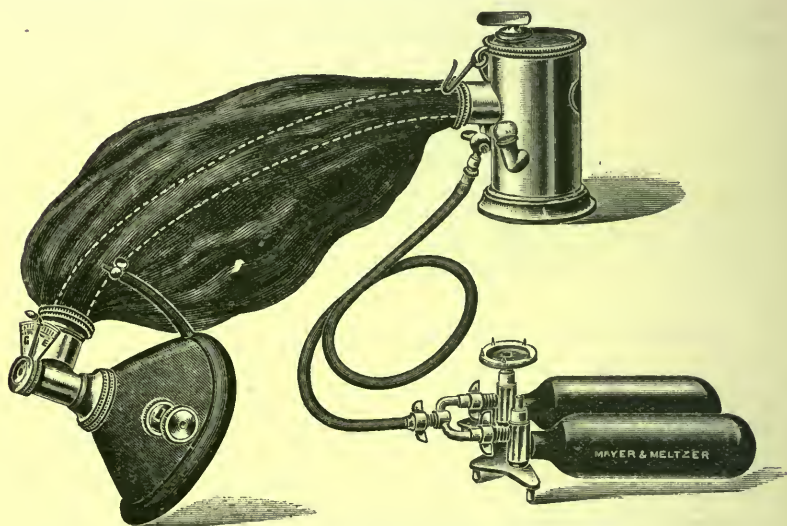
FIG. 41.—Apparatus for the nitrous oxide and ether sequence.
In the figure the ether tap is turned on, but the N₂O tap is turned off.

the face-piece which opens two apertures, one admitting gas, the other ether. The whole apparatus is light, and is suspended by a hook from the administrator's buttonhole.*

The gas-supply is controlled by the foot, which, placed upon the foot-piece, rotates it from right to left to turn the gas on, and from left to right to turn it off.

Fig. 42 shows a section of the ether chamber. The arrows indicate the route by which the mixture of the anæsthetics passes from the chamber into the central tube and Cattlin's bag.

To avoid the obvious difficulty of cleansing the older forms

* The apparatus is made by Messrs. Mayer and Phelps of London.

of the inhaler, Messrs. Mayer and Phelps have constructed for
me the apparatus figured below (fig. 43). In this all the parts
are easily disconnected, and the metal parts can be boiled while
the rubber portions can be carefully sterilised with carbolic acid
lotion (1 in 20). The rubber face-pieces must not be boiled, so
that when a tuberculous or septic patient is to be anæsthetised
a metal face-piece can be used and boiled after use. A com-
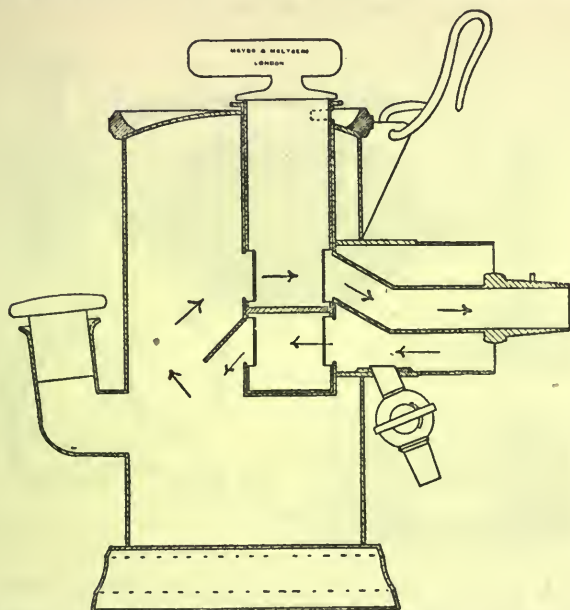
FIG. 42.—Section of ether chamber of Clover's inhaler.

The arrowheads indicate the directions in which air or gas passes into the
ether container, and having traversed this, passes out and taking up ether
vapour reaches the patient. In the diagram the ether tap is shown open
and the gas tap closed.

parison of the figures will give a clearer idea of the inhaler than
verbal description.

The advantages of this apparatus are :—

The absolute control the administrator possesses over the
strength of vapour with which he is working ; thus, he can
commence the administration with pure gas, then permit some
gas to pass over the ether, and by degrees increase the strength
of the vapour to full ether without exciting spasm or cough :

Its great simplicity and portability. It has been termed unsightly and cumbersome, but no one familiar with its use would find it either the one or the other.

The same apparatus is equally satisfactory when either ether or nitrous oxide gas has to be administered unmixed, since with care and proper cleanliness the rubber can be kept without smell, and the ether is completely cut off from the rest of the apparatus when the tap of the ether chamber is closed.
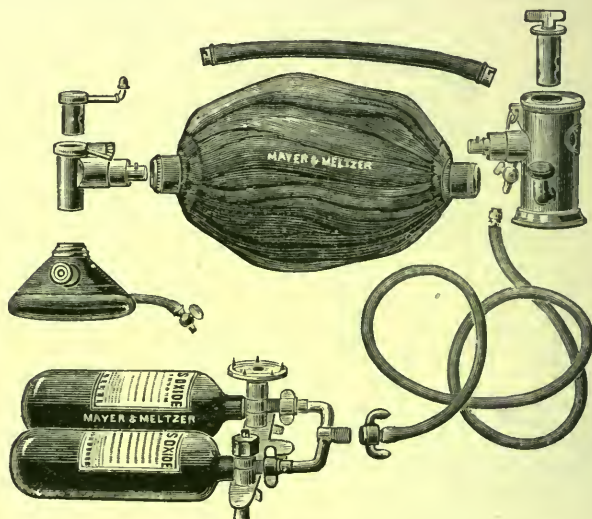
FIG. 43.—Dr. Dudley Buxton's modified ether inhaler.

The parts are shown separated from each other, thus indicating how they can be cleaned and sterilised before use. The tube shown above the bag passes through it, and yokes with the ether reservoir and the metal mount which connects with the face-piece.

To anæsthetise by this method the indicator, which is seen on the dial attached to the metal connexion between the gas-bag and the face-piece, is turned so as to be completely off the dial-plate. This opens the air-way. The nitrous oxide tube is then fixed to the gas tube attached to the ether chamber; this is controlled by a stopcock on the ether chamber connexion. The Cattlin's bag is then slowly filled with gas to two-thirds of its capacity. The bag should have the capacity of at least two gallons of gas. The face-piece is then applied and carefully fitted, the excess of air in the air cushion being liberated. When the patient is accustomed to the face-piece, that is in

three or four respirations, the indicator is turned during an inspiration on to the dial-plate to opposite the letter G, which stands for "gas." The patient is now breathing nitrous oxide, and the administrator from time to time admits more gas into the bag. When the breathing, which at first is usually hurried and irregular, owing to the patient's nervousness, has settled into a quiet regular rhythm, the tap of the ether chamber is opened. Now the indicator is slowly moved over the dial from the letter G (gas) towards E (ether). If no check in the respiratory rhythm takes place, the ether vapour is made stronger and stronger, until, on the indicator reaching E, full, *i.e.* about 30 per cent., ether vapour is inhaled. If, however, the breath is held or cough occurs, the indicator must be put back for a respiration or so until toleration of the ether is attained. The supply of gas should be kept up to this point, but as soon as the indicator is at E the nitrous oxide is cut off by turning the foot-piece to the right, and the indiarubber tube is detached, but the gas tap is left open to admit air. As soon as the patient breathes the ether freely and conjunctival reflex has grown sluggish, the face-piece is lifted, and the gas expelled from the bag. This may, in exceptional cases, be required sooner, the indication being marked cyanosis and respiratory embarrassment or sudden pallor.

Slight cyanosis and breath-holding are not necessarily signs for admitting air. If the face-piece is lifted too soon the patient will rapidly "come out" of the nitrous oxide narcosis, and his blood not being sufficiently charged with ether, he will commence to struggle. On the other hand, if the ventilation of the lungs by admission of air is delayed too long, respiration will be seriously impeded and the heart become embarrassed. One if not more deaths have occurred through this accident, although the watchful administrator can hardly overlook the obvious signs of danger, such as weakening of respiration associated with deep cyanosis.

Care must be taken that the face-piece fits accurately, as if air leaks in around the air pad attached to the face-piece the patient will breathe very softly and draw the air in, but get little or no ether. When once muscular relaxation has occurred and the breathing is regular, the rules given above will guide the anæsthetist; air will have to be admitted at this stage from time to time, and all cyanosis carefully avoided. The gas tap should

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be kept open in order that air may be drawn in by the patient's inspiration. When, owing to respiratory spasm, or persistent cyanosis, oxygen seems indicated, it can be admitted through this tap.

ETHYL CHLORIDE FOLLOWED BY ETHER.

The portability of the rapidly evaporating anæsthetics like ethyl chloride and its mixtures renders them useful when nitrous oxide is unobtainable.

Many ways have been suggested by which the ethyl chloride may be given in sequence with ether, and reference must be made to a later chapter dealing with ethyl chloride more in detail for particulars and technique of the methods suggested.

The only essential for the closed method is that complete exclusion of air is effected while the ethyl chloride is being administered. When ethyl chloride is given by an open method the plan to be adopted is somewhat modified, and is described in the section dealing with that anæsthetic (p. 314).

When separate inhalers are employed, the ethyl chloride (3 to 5 c.c.) is sprayed upon the inside of the mask according to the age and physique of the patient, and this is at once applied, all air being excluded. In 20 to 30 seconds stertor will be heard. The mask is then rapidly changed for a Clover's ether inhaler, already filled and arranged so that the patient at once breathes a full strength ether vapour.

But two inhalers are not necessary. The appropriate dose of ethyl chloride can be sprayed into the bag of the Clover's inhaler, and as soon as unconsciousness is obtained the ether may be turned on.

CHLOROFORM OR ITS MIXTURES FOLLOWED BY ETHER.

The A.C.E., or better the C.A. or the C.E., is occasionally employed as an introducer to ether inhalation, an open mask such as Skinner's or Schimmelbusch's being used and the mixture dropped upon it until struggling commences or unconsciousness is established, when ether is given by an open method or by an inhaler. If chloroform is used, the same procedure is adopted.

The employment of these sequences is open to the obvious objection that chloroform or one of its mixtures is being employed

at the period of its greatest danger, *i.e.* during the induction. If there is any real reason for using chloroform before ether it is best done by introducing the anæsthetic by means of the Vernon Harcourt chloroform regulator. But as some nervous persons are terrified by any apparatus, this may be preceded for a minute or two by an open mask and a drop method. When morphine and scopolamine and atropine have been introduced an hour before the inhalation it is wise to deepen the narcosis by using a mask and drop method before passing to " open " ether, should that method have been selected for the final anæsthetic.

The employment of **oxygen** with ether, which I have adopted for many years, is of great value. In cases in which the induction presents unusual difficulties from dyspnœa, spasm, cough, holding of the breath, struggling associated with cyanosis, in alcoholics, and in persons of feeble vitality, the repeated filling the bag connected with the ether inhaler with oxygen removes all difficulty, and rapidly induces quiet anæsthesia. The narcosis so obtained is more profound than can be ensured when using ether by itself, as the hyperoxidation of the tissues enables more ether to enter the circulation than could otherwise occur without danger to the nervous centres, hampered as they probably would be by deoxidised blood. The plan I pursue is to admit the oxygen through a second tube fitted to the Clover's gas and ether inhaler *pari passu* with the ether, and either give the oxygen intermittently or continuously as occasion seems to demand. The oxygen certainly acts as a powerful stimulant, and is very valuable in prolonged and exhausting operations as a corrective to shock.

3. NASAL METHOD—PHARYNGEAL ANÆSTHESIA.

Mr. H. M. Page * has adopted Dr. G. Crile's method of introducing ether vapour through the nasal passages in cases in which it is desirable to leave the air-way free for operation. The principle is to shut off the mouth cavity from the upper air-passages, so as to prevent aspiration of blood or septic material, and to remove the anæsthetist and his paraphernalia from the site of operation. A preliminary tracheotomy and

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* *Lancet*, 1909, vol. ii. p. 364 ; *Brit. Med. Jour.*, Sept. 14, 1912.

plugging of the larynx involves certain risks, so if a nasal venue for the anæsthetic is possible, it is a gain to the patient.

Method.—The mouth, nares, and naso-pharyngeal space should be carefully cleansed by spraying, gargling, or other means, and the patency of the nares be investigated.

If the lumen of the passages is lessened by tumefaction and congestion of the turbinates, a pledget of cocaine and suprarenin * may be inserted, or the mucous membrane wiped with a mop holding cocaine, until ischæmia is established.

Anæsthesia is now obtained by ordinary means, and it is usually wise to prepare for it by a hypodermic injection of morphine, scopolamine, and atropine given one hour previously. Mr. Page suggests morphine gr. $\frac{1}{4}$, atropine gr. $\frac{1}{75}$.

As soon as the patient is fully anæsthetised, and has taken sufficient ether to ensure his remaining quiet for some minutes, the tubes (see fig. 44) are introduced into the nares until the lower ends are opposite the epiglottis, and then the mouth is well opened with a gag of wider stretch than is commonly obtained; the pharynx is carefully and systematically packed, the tongue being drawn forward out of the mouth. A sterilised gauze roll $1\frac{1}{2}$ to 2 inches wide answers well, and this must be introduced so that the sides as well as the centre of the pharynx are completely shut off from the mouth. In packing, care must be taken to avoid compressing the tubes, especially since it is essential that the packing should close in the outer sides of the tubes. The apparatus, which is figured, consists of two nasal rubber tubes, of sufficient size to block the nares, and these are connected by a Y-shaped glass piece with a wider bored tube. This, again, if open ether by a drop method is to be used, is fitted to a glass funnel covered with gauze. Mr. Page finds that in many cases the funnel is best replaced by a connexion between the tube and a Vernon Harcourt chloroform inhaler, thus giving chloroform instead of ether. Oxygen can be supplied with the anæsthetic. For operations about the mouth a light narcosis is required, so that a " faint corneal " reflex (Page) should be retained throughout.

Kühn intubates with his special apparatus. The tube is con-

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* The danger of the use of suprarenal extracts when chloroform is to be used must not be forgotten; indeed, when that anæsthetic is adopted the suprarenin should not be employed. It is not necessary, as cocaine is itself a vaso-constrictor.

tinued some way out of the mouth to a funnel covered with
domett.   On this ether is dropped.

Mr. Souchon * has devised an ingenious instrument for effecting
pharyngeal anæsthesia.   It is worked by a hand-pressure ball.
The same procedure is carried out in a different manner by
Dr. H. R. Thoms.†   He employs a somewhat complicated appara-
tus, which allows a plenum ether vapour atmosphere to enter
the naso-pharynx by admitting oxygen under pressure to an
ether chamber, which is kept warmed by an electric heater, and
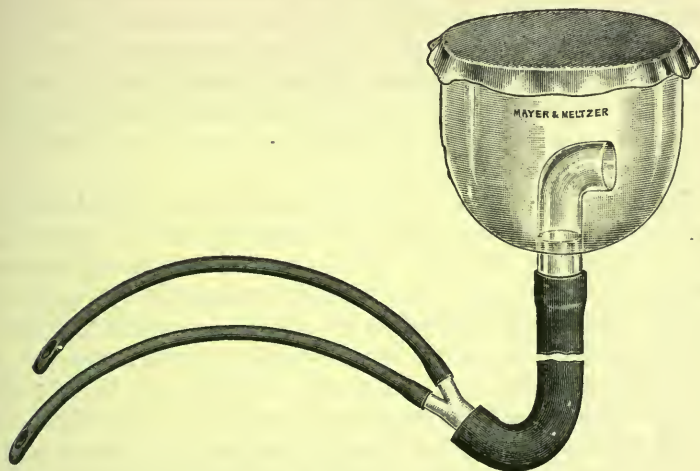
FIG. 44.—Crile's tubes for nasal etherisation.

the ether, passing thence by a soft catheter through the nares,
enters the post-nasal space.

B. INTRATRACHEAL INSUFFLATION OF ETHER.

I have employed the term " intratracheal " rather than that
of endotracheal, since the former has been more generally
adopted.   The method has since 1914 become an essential addi-
tion to the anæsthetist's armamentarium.   War surgery requires
special methods for extensive reparative operations on the jaws,
the face, and air-passages.   Intratracheal insufflation answers

* *Med. News*, Philadelphia, Nov. 23, 1895, and " Surgery, Gynæcology,
and Obstetrics," vol. xiii. p. 169.

† " Surgery, Gynæcology, and Obstetrics," 1911, vol. xiii. p. 695.

admirably for such cases ; it enables the anæsthetist to regulate the depth of narcosis, and leave the field of operation wholly at the disposal of the surgeon. Its use prevents the danger of introducing sepsis either from the apparatus, the hands of the anæsthetist, or through the patient's vomiting. Further, it permits the use of ether rather than that of chloroform in very many cases in which the former is the more desirable anæsthetic, both on account of the state of the patient and the requirements of surgery. The method has been proved most valuable not only for the above types of operation, but also in military as well as in civil practice for extensive operations upon the jaws, the tongue, mouth, œsophagus, upper air-passages and associated air sinuses, for goitres, although not for those met with in Graves' disease. Surgical procedures involving the thorax or abdomen are also in many cases facilitated by the use of the intratracheal method.

Tuffier (1897), Kühn, and Lotsch employed laryngeal intubation to produce plus pressure in the lungs as well as anæsthesia, but the inception of the method, as applied to promoting anæsthesia for surgical operations, was rendered possible through the experimental work undertaken by Drs. S. J. Meltzer and John Auer of New York,* while its practical application we owe in no small part to Dr. C. A. Elsberg † of New York. Meltzer and Auer demonstrated that, if a catheter two-thirds of the diameter of the trachea is introduced into it nearly to its bifurcation, respiration with full aeration persists, but with lessened respiratory movements. They urge that as a result of their method (1) "The lungs are kept in [a] continuous inspiratory state of distension, which facilitates the exchange of the gases. (2) The fresh air enters the lowest part of the trachea. (3) The [expired] air escapes by another path (although also through the trachea) than by the one it enters."

Before dealing with the purely practical aspects of the intratracheal insufflation method it may be well to sum up briefly Dr. Meltzer's conclusions. Not only does his high reputation

* *Jour. of Experimental Med.*, 1909, vol. ii. p. 622, " Continuous Respiration without Respiratory Movements," by S. J. Meltzer and John Auer. From the Rockefeller Institute for Medical Research.

† See " Annals of Surgery," vol. liii. p. 161, for a description of Dr. Elsberg's apparatus, and for the record of his observations upon the method.

lend weight to these, but as he has published his experiments
it only remains for us to accept as proven the basis upon which
the method is founded. It would be difficult to find any finer
piece of experimental work than Dr. Meltzer's researches bearing
upon the subject under treatment. The principle of the effect-
iveness of the method is based upon its cutting out the greatest
part of the dead space in the respiratory mechanism, since the
ether vapour and air are carried by the intratracheal tube
directly to the bronchi at the bifurcation of the trachea. Thus
less ether is required to induce and maintain anæsthesia. The
outgoing current of air escapes with so much force, since a plus
pressure has been established in the lungs, as absoluely to prevent
mouth aspiration, thus protecting the patient from the entrance
of infective material from the mouth or pharynx. Particles of
charcoal were introduced into the pharynx of animals which were
kept for hours under intratracheal ether anæsthesia, but none
gained access into the trachea. Also these animals were made
to vomit, and in spite of this no foreign material entered the
air-passages.

He proved further that introducing the catheter, if done with
care, and maintaining it in the trachea even for hours, caused
no inflammation or infection of the air-passages, no laryngitis,
tracheitis, bronchitis, or broncho-pneumonia ensuing. Dr.
Meltzer compares the trachea with the urethra, in that in neither
case need trauma or infection follow the introduction of a catheter.
A further advantage is that the reflexes, often a hindrance to
the surgeon, which arise in the regions innervated by the tri-
geminal and superior laryngeal nerves, are absent when the
anæsthetic is introduced directly into the trachea.

Limits of safety.—When the amount of ether administered
exceeds the dose necessary for anæsthesia, the spontaneous
respiration becomes shallow and eventually ceases, while a
little later the blood-pressure slowly falls. The pulse-pressure
sustained to this point now becomes rapidly smaller, and the
animal is in extreme danger. If the dose of ether is lessened
or cut off altogether, the blood-pressure rises and later spon-
taneous respirations again appear. Dr. Shipway tells me he
has seen this procession of events occur three times in the human
subject, and in every case complete recovery was readily brought
about. The cessation of spontaneous respiration is due to in-
toxication of the medullary centres by ether, and serves as a

signal of this danger, hence a state of apnœa should be sedulously avoided.

Dr. Meltzer found it difficult to kill dogs when giving them ether by the intratracheal route. It took ten hours continuous administration to effect his purpose.

Dr. Meltzer's experiments * prove further that the size of the intratracheal catheter is important : if too large a rapid and deep anæsthesia ensues and a cessation of spontaneous respirations soon occurs. Such a tube is dangerous, as it interferes with expiration, which should take place round the catheter, between it and the tracheal wall, and so leads to accumulation of carbon dioxide, while it increases intrapulmonary pressure even in spite of the use of a safety valve. Dr. Meltzer advises the use of No. 23 French for ordinary patients and No. 24 for alcoholics. The symptoms occasioned by too large a catheter are : spontaneous respiration soon becomes too slow, expiration grows prolonged, active, and laboured, and later, cyanosis supervenes. If the catheter is too small inadequate anæsthesia results, and this is remediable by exerting pressure with the finger over the hyoid bone just above the thyroid cartilages for a few seconds four or five times in a minute. Dr. Meltzer deprecates allowing air to bubble *through* the ether, as there is a danger of liquid ether being propelled into the lungs, with a fatal result. The pressure as gauged by the manometer to which the safety valve actuates should be 20 mm. Hg, but when the catheter is small a pressure of 25 or 30 mm. is not too high. In this connexion it may be pointed out that pressure upon the trachea, as, for example, through faulty position of the head and neck, may interfere with expiration and lead to dangerous increase of intrapulmonary pressure. Dr. Pembrey and Dr. Shipway † have made some physiological observations upon intratracheal insufflation of ether. With a ventilation of 30 litres or over per minute apnœa was caused through excessive loss of carbon dioxide from the blood, but the pulse remained good and blood-pressure was 150 mm. Hg. Such apnœa is unnecessary, and is,

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* Dr. Meltzer (*Proc. International Med. Congress*, 1913, subsection "Anæsthetics") gives a valuable exposé of the method, and figures a simple but efficient form of the intratracheal insufflation apparatus which he has found to work as well as the more elaborate forms.

† *Proc. Roy. Soc. Med.*, vol. vii. No. 5, 1914, section of "Anæsthetics," p. 34.

moreover, deleterious, as Meltzer has shown. The persistence of spontaneous respirations favours gaseous exchange in the lungs, it proves that the pressure of the entering air is not too great for the effective action of the respiratory muscles when weakened by the action of the anæsthetic, and further it gives an indication of the activity of the respiratory centres. Analysis of the alveolar air has shown that, with a ventilation of 16 litres per minute, the pressure of carbon dioxide is 5 to 6 per cent. of an atmosphere; and respiratory movements are definite. Mr. Geoffrey Marshall * examined the blood-pressure of patients kept anæsthetised by this method, and found very slight fall even after a long operation, and the response to strong peripheral stimulation, "insult to tissue," was as active at the conclusion as during the early stages of the operation. During apnœa the blood-pressure falls.

Finally, as Meltzer has pointed out, the intratracheal method affords a most excellent way of performing artificial respiration.

The Technique of Intratracheal Ether Insufflation.

Although there are various forms of apparatus, each possessing merits of its own, they agree in general principle. There is an ether reservoir which is kept warmed: Meltzer and Githens have shown that effectiveness of the etherisation is proportional to the diameter of the ether reservoir, and that the smaller the space in the reservoir above the surface of the ether the more rapidly is anæsthesia produced. Air, or if need be, oxygen, is driven by an electric motor or foot-bellows,† through bottles passing through which it is sterilised and moistened. It is then conveyed through tubes to the catheter, and so into the patient's lungs. The pressure of the ether-supply is indicated by a manometer, its temperature is shown by a thermometer, while a blow-off mercury valve enters into the circuit to prevent excessive intrapulmonary plus pressure. This last, as indicated above, should be arranged to keep the pressure between 20 and 35 mm. Hg as the case may require.

The patient is prepared in the ordinary way, and atropine gr. $\frac{1}{100}$ given one hour before the operation.

Although some persons give morphine also, it is probably safer

* *Op. cit.*, p. 35.

† It is wise always to have a foot-bellows and connexions at hand in case the electric motor fails.

not to use this drug in cases of extensive operations on the jaws, tongue, goitre, etc. The patient is now fully anæsthetised by ordinary methods, and when completely relaxed he is ready for the passage of the catheter.

A fairly rigid silk-woven catheter, 30 cm. long, with an opening at or near its end, is selected. Two marks are made upon it, one 23 cm. and one 26 cm. from the tip. If this latter mark is opposite the incisor teeth, the end will be 5 cm. above the bifurcation of the trachea.* The size of the catheter selected will depend upon the diameter of the trachea ; one, the diameter of which is about half the length of the glottis, easily judged by direct inspection, will be best. The average for the adult is 21 for women, 22 for men. If deep anæsthesia is required, then 23 or 24, but for mouth or goitre or gland cases, 21 or 22, and 18 to 20 for young people. Dr. Elsberg finds that the length of the catheter between the teeth and the glottis is about equal to the length of the catheter below the glottis. The catheter is introduced by means of Jackson's direct laryngoscope, in the same way as when that instrument is used to introduce the bronchoscope. The instrument is passed along the posterior pharyngeal wall, and the epiglottis comes into view and can be kept well forward by the beak of the laryngoscope, which exposes the opening of the rima glottidis. This is at times a little difficult, but can usually be done by moving the head in one direction or the other, though keeping it fully extended. It is well to let the head be thoroughly extended and the mouth gagged and widely open, the epiglottis being held forward by the back of the laryngoscope. The catheter is introduced through the instrument, and pushed on until the 26 cm. mark is opposite the incisor teeth. The anæsthetist should *see* the catheter pass through the larynx, as this is the only real proof of it having found its right objective. To do this direct vision with the laryngoscope is essential. Some spasm may occur as the larynx is entered, but this soon passes off, and as soon as the catheter is connected the air will be heard to leave the trachea with a hissing sound, evidencing its patency and correct position. The utmost gentleness should be used in passing the catheter ;

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* According to Brüning the average length of the male trachea is 12 to 13 cm., that of the thyroid 5 cm., and the distance from the glottis to the incisor teeth is 14 cm., while in females the measurements are slightly less.

if it is pushed too far cough will be excited, if not far enough the narcosis will be too light and ephemeral. Kinking of the catheter or of the trachea may occur, causing cyanosis. This accident is easily detected, since normally in this plan of anæsthetisation the face has a cherry red hue. The catheter may pass into the œsophagus and either curl up on itself or pass down and inflate the stomach, accidents arising through ignorance of the method or carelessness.

In cases in which there is reason to avoid a preliminary general anæsthetic, and there are such, thorough cocainisation of the larynx with or without a preceding course of bromides will enable the anæsthetist to pass the catheter on a conscious patient, but this procedure is usually terrifying to the patient; even although he feels no pain he may struggle during the necessary manipulation.

An arrangement of wire running below the nose, and hooking over the ears like a spectacle-frame, can be used to hold the catheter in position, or it can be fixed by a piece of strapping. After connecting the catheter up, the pressure should be kept at about 20 mm. A higher pressure is said by some authorities to be free from danger, although obviously a prolonged markedly plus pressure in the lungs is a condition making for undesirable developments. It is wise occasionally to permit voluntary respiratory movements of normal amplitude to take place, otherwise cyanosis and heart strain are apt to be caused. Cyanosis, however, may be due to other causes, viz. that the catheter has too large a diameter, or is not pushed far enough into the trachea, and when these errors are corrected the normal colour of the patient returns. On the other hand, if the catheter is introduced too far it sets up spasm and coughing, which are at once relieved by a slight withdrawal. During the insufflation the expired air, mucus, and so on, pass up and out beside and around the catheter, so that no aspiration of blood or other fluid can ever take place, owing to the strong up-draught. After-effects are, as a rule, absent. True apnœa should never occur, although when the catheter is first introduced some holding of the breath takes place. The respiratory movements, although slight, should be quite definite. If they cease, cutting out the ether and insufflating with oxygen at once clears up the condition.

When the operation is completed and the ether-supply is shut off, the lungs should be thoroughly ventilated with sterilised pure

warm air or oxygen to rid them of any ether vapour. This of course can be done by means of the insufflator apparatus.

The depth of anæsthesia is a most important matter, and one of the great merits of the intratracheal method is that it gives the anæsthetist complete control over the anæsthesia. It is now fully recognised that light but sufficient anæsthesia is to be aimed at and maintained. If this is achieved the most un-promising cases can be dealt with and serious after-effects avoided. Indeed, deep narcosis should be recognised as a danger, and so should seldom, if ever, be permitted to occur.

Difficulties and Dangers.

These, as has been pointed out, are due in the main to some error in technique. The catheter may damage the larynx and cause soreness or worse after the inhalation; it may go astray into the œsophagus, or in cancerous cases bore a hole in the wall of the air-passage, or become coiled up on itself. When no efficient valve is provided, and when the manometer is neglected, the pressure in the lungs may cause over-distension and inter-stitial emphysema result. Overdosage may occur unless spon-taneous respiration is closely watched, since when oxygen is being administered with the ether; cyanosis will not be seen.

As has been pointed out, spontaneous breathing, even if slight, should never be abolished, and indeed should be allowed to in-crease from time to time for a few seconds by lessening the pressure of the ingoing air-ether stream. When once full anæs-thesia is established a lighter grade of narcosis should be em-ployed, as this is the best safeguard against overdosage. Failure to obtain due relaxation has been reported in a few cases of abdominal sections.

Sequelæ are seldom of a grave character provided meticulous care be taken in carrying out the details of the method. The use of WARMED ETHER VAPOUR is essential, since the natural warming arrangement—the passage of the anæsthetic through the mouth and nose—is out of action. When warmed vapour is used, even bronchitic patients are not seriously hampered by the ether given by this method.

Types of Cases suitable for the Intratracheal Method.

Dr. Shipway * points out that shock is lessened and the con-tent of carbon dioxide maintained at its norm, hence the system

* *Proc. Roy. Soc. Med.*, March 1914, section " Anæsthetics."

is called for when severe surgical proceedings are proposed, also for debilitated patients, *e.g.* in severe anæmia or cachexia; for patients whose spontaneous respiration is obstructed, *e.g.* operations on the mouth, nose, pharynx, and neck, also in cases in which there is hæmorrhage into the air-passages, *e.g.* (1) gunshot wounds of the face, mouth, and pharynx, (2) malignant and
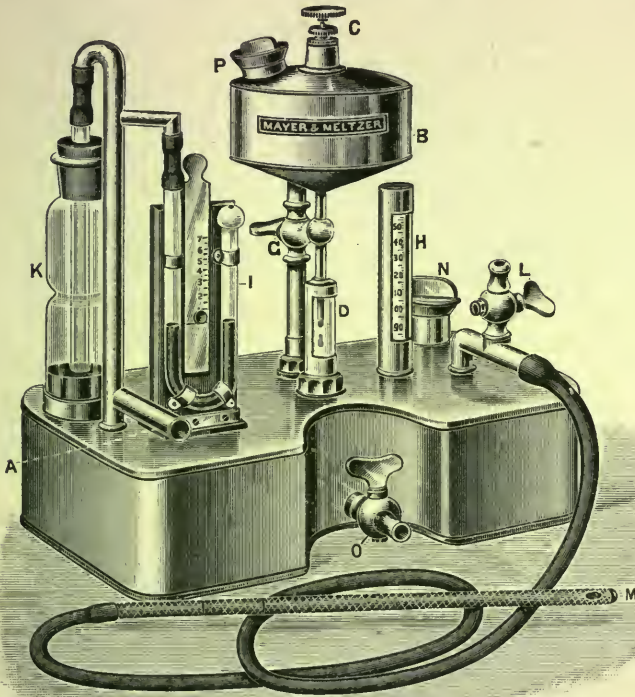
FIG. 45.—Dr. F. E. Shipway's intratracheal ether insufflator.

A, air inlet for connexion with foot pump or rotary motor pump; B, ether container with funnel for pouring in ether and tap for emptying; C, screw tap for regulating flow of ether; D, dropping chamber which allows the flow of ether to be kept under observation; G, equalising tube with tap for preserving equality of pressure on upper and lower surfaces of ether, thus ensuring regular delivery; H, thermometer; I, mercury manometer with adjustable scale; K, mercury safety-valve, should blow off between 20 mm. and 25 mm. of mercury; L, tap for reducing the volume of air stream at intervals; M, intratracheal catheter and tubing; N, filling funnel for hot-water chamber; O, emptying tap for hot-water chamber; P, filling funnel for ether container.

non-malignant disease in these regions*; for face and head cases; for operations on the upper abdomen.

Types of Apparatus.

One of the best apparatus in use in this country is that devised by Dr. Shipway.† The illustration (fig. 45) will assist the reader to understand the working of the instrument. The idea underlying the apparatus is that ether drips from a container into a central chamber, through which passes the air current from the motor or foot bellows, and is there vaporised, partly by this means and partly by the heat supplied by an encircling hot-water jacket. The tap C regulates the flow of ether, which can be delivered in drops or in a continuous stream. The tube G, connecting the ether container and the vaporising chamber, equalises the pressure on the upper and lower surfaces of the ether, and regular dropping is ensured. During anæsthesia the tap of the equalising tube must be kept open, but if the container needs refilling during an administration this tap must be first closed before the bung of the filling funnel is removed, and kept closed until the bung has been replaced. At the end of anæsthesia the container can be emptied by means of a tap. The thermometer should register 110° to 120° F., according to the temperature of the room and the nature of the operation. A Y-piece provided with a tap is fixed in the tubing from the motor for attachment to an oxygen cylinder. The hot-water jacket stands in a non-conducting cover. The apparatus is simple and compact; it weighs $5\frac{1}{2}$ lb. and measures $8\frac{1}{2} \times 4\frac{1}{2} \times 12$ inches. Dr. Shipway regards cocainising the epiglottis and adjacent structures as an unnecessary preliminary step to catheterising the larynx, although it may assist the beginner when dealing with difficult cases.

Mr. Kelly's ‡ apparatus consists of a $\frac{1}{6}$ h.p. electric motor actuating a rotary blower—hypreso, size OO—which introduces the blast of air into a cleansing chamber containing water, thence it travels to an ether chamber constructed upon the "surface carburetter" principle. The pointer is the control, and by turning it to Full all the air passes over the ether, or turning it to O no ether mixes with the air. Intermediate strengths of

* *Lancet*, 1919, vol. ii. p. 1030.
† *Ibid.*, Aug. 5, 1916.
‡ *Brit. Med. Jour.*, 1912, vol. ii. pp. 112 and 617.

ether are obtained by intermediate positions of the pointer.
The air and ether vapour then pass through a coil of lead tubing
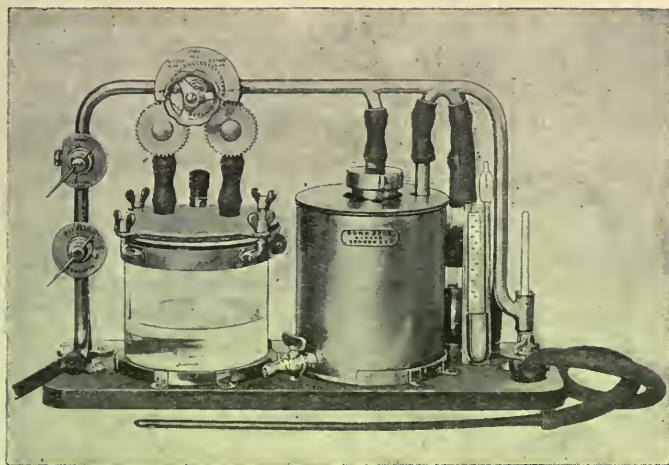
FIG. 46.—Mr. R. E. Kelly's intratracheal insufflator.
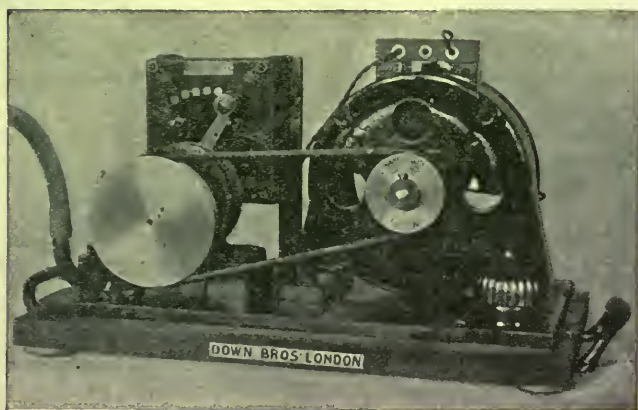
FIG. 47.—Motor actuating Mr. Kelly's insufflator.

which is kept at the required temperature by an electric hot-
plate controlled by a switch. A manometer and thermometer
are placed in the circuit between the heater and the tube which
connects with the intubating catheter.

Mr. Boyle's apparatus * is figured and described below.

Mr. Boyle has modified it to the extent of having both the ether container and water-bottle made of metal instead of glass. It will be noted that no safety-valve is used, but this Mr. Boyle assures me does not militate against its safety, since the air is propelled solely by using a foot bellows, and so the pressure employed is always and immediately under the control of the
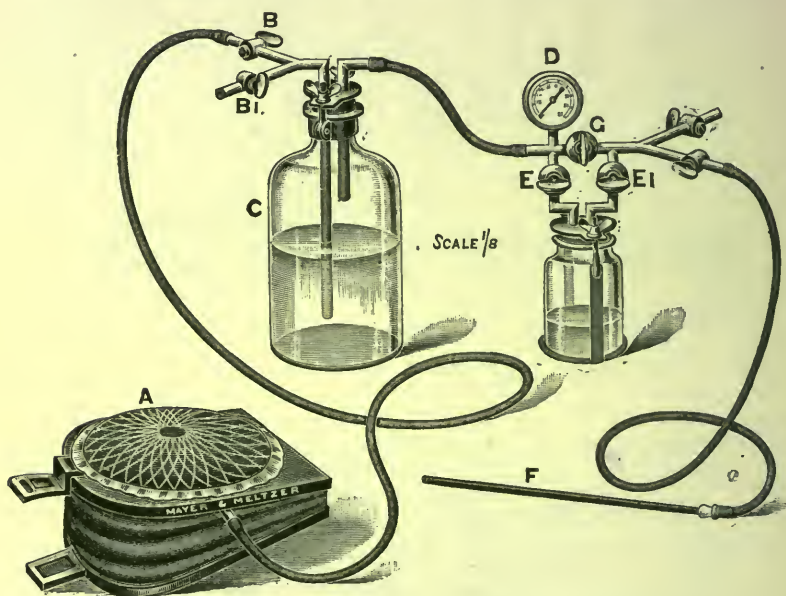
FIG. 48.—Mr. Boyle's ether insufflation apparatus.

Air is driven from the bellows A, through hot water in the bottle C (the tap B is for air, and B1 is a reserve tap for oxygen if necessary). The air then passes through E, over the surface of the ether in the smaller bottle, and so on to the gum-elastic catheter F. When it is desirable to give air without ether, E, E1 are turned off and G is turned on. By regulating these taps it is quite easy to have either the whole or part of the air laden with ether vapour. The manometer D registers the pressure under which the air is driven into the trachea.

anæsthetist, who can graduate the force and frequency of the action of the bellows accordingto the requirements of the patient.

The apparatus devised by Dr. Ehrenfried † is at once simple

* See *Lancet*, Nov. 30, 1912.
† *Boston Med. and Surg. Jour.*, vol. clxiv. No. 15, 1911, pp. 532–5.

and portable. It consists of a Wolff's bottle with three necks, sitting within a copper water jacket, and a foot bellows. By means of stopcocks on the outside of the jacket the stream of air from the bellows can be carried through the hot water over the surface of the ether (contained in the Wolff's bottle) or through the ether when a particularly strong vapour is desired. Air and ether vapour may be mixed in any proportion. Connected with the delivery end of the apparatus is a safety-valve and pressure regulator consisting of a bottle of mercury into which a tube is plunged. The depth of the tube in the mercury, which is adjustable, represents the maximum of pressure which is allowed within the apparatus ; if, for any reason, such as a spasm of the glottis, the pressure should rise, the valve " blows off automatically and danger from interstitial emphysema is avoided." The temperature of the ether and air should be 10° F. above room temperature. The catheter is passed into position by an introducer, a laryngeal forceps with sleeves attached for grasping the tube near its extremity similar to the Doyen introducer. The left forefinger is placed on the epiglottis, and the instrument introduced without the use of head mirror or electric illumination.

Dr. Boothby and Dr. Cotton use nitrous oxide and oxygen by the intratracheal route, and insist upon the importance of warming the gases before these enter the lungs.*

C. Intravenous Ether Infusion.

To Burkhardt † we owe the method of introducing ether directly into the blood stream. The success which followed experiments upon the lower animals led him and others to employ it for man, but the first attempts, although successful, revealed the necessity for a special apparatus and technique. Experience has proved the superiority of employing a *continuous* instead of an intermittent flow into the vessels.

H. Küttner, one of the first to use the method in surgery, has cautioned against the danger of air embolus and thrombosis, but these dangers are greatly diminished by the continuous flow system. Goyane's ‡ advocacy of the plan of introducing the ether and saline into an artery has not been responded to ;

* *Boston Med. and Surg. Jour.*, 1912, vol. i. p. 486.
† " Archiv. of Experiment. Pathol. and Pharmacol.," Bd. 61, p. 323.
‡ *Siglo Medico*, Oct. 9 and 16, 1909.

indeed, the advantages claimed for the method hardly counter-balance its obvious dangers. Thus much had been demonstrated in the very early days of ether anæsthesia alike by Flourens and Claude Bernard. Prof. August Bier, Dr. J. L. Ransohoff, and others sought to avoid these perils by localised intravascular injections of various drugs cut off from the general circulation by tightly-fitting bands, but this procedure is of limited applica-tion. As we know intravenous infusion at the present time it is confined to the use of ether, hedonal, and isopral (see below), less frequently with that of paraldehyde.* Chloroform em-ployed in this way is extremely dangerous. Dr. F. S. Rood † has elaborated an apparatus for ether (fig. 49). This consists of a glass reservoir (A) capable of holding about three pints of saline containing ether, supported on a stand eight feet above the floor level. This reservoir is controlled by a ground-glass accurately-fitting stopcock on the drawn-out end of the reservoir and is connected by a rubber tube with the regulating chamber (B). This has three openings, one uniting it with the reservoir, one connecting it by a rubber tube with the warming chamber controlled by an accurately-fitting glass stopcock, and one which admits air, is capable of airtight occlusion by means of a rubber or ground-glass stopper. Personally I prefer the former, i.e. the rubber stopper, as less liable to jam. When the reservoir tap is opened and the regulating-chamber tap is closed, the saline-ether solution enters the regulating chamber, and as soon as this is half full the air inlet is closed by inserting the stopper, as a result the air in the chamber becomes compressed by the fluid in the chamber, so that the fluid, as it escapes from the regulating chamber into the warming chamber, is under pressure, and so passes in a continuous flow into the tube connected with the cannula. The warming chamber is immersed in warm water, the temperature of which is regulated according to the state of the weather, the object being to warm the saline to a temperature below that at which the ether escapes in bubbles. This chamber, which is constructed of glass, has its egress tube nearly half-way below its summit in order that any air or volatilised ether may rise to the top of the chamber while only fluid traverses the egress tube. This last is connected by a rubber tube, roughly

* *Lancet*, Nov. 2, 1912, p. 1220.
 † *Brit. Med. Jour.*, 1911, vol. ii. p. 974 ; 1912, p. 608 ; and *Proc Roy. Soc. Med.*, 1912, vol. v., pt. I. p. 77.

the diameter of the dis-
tended vein, with a glass
or metal cannula which is
to be introduced into the
vein.

A 5 per cent. solution of ether
in normal saline flows from a
reservoir, which is fixed 8 feet
above the floor level, through
the indicator, and then through
a warming chamber into the can-
nula, and so into the vein. The
indicator consists of a cylindrical
bulb with a capacity of 8 ozs.
When the apparatus is working,
the lower half is full of the solu-
tion, while the upper half con-
tains air. The solution flows
from the reservoir into the bulb
through a pipette, and drips on
to the surface of the fluid below.
The system being a closed one,
the pressure within it is trans-
mitted through the indicator by
means of the air contained there-
in ; hence it follows that the rate
at which the solution drips from
the pipette furnishes a satisfac-
tory index of the rate at which it
is entering the vein. The flow is
entirely controlled by one tap
placed immediately below the
indicator.

A. Reservoir with stopcock,
holding about three pints of the
ether-saline solution.

B. Indicator with stopcock
and air inlet.

C. Warming chamber in cop-
per hot-water receptacle.

D. Arm rest.

The apparatus can be supplied
with two reservoirs, one to con-
tain the ether solution, and the
other normal saline with V-shaped
connexion in order that saline
may be turned on immediately
if required.
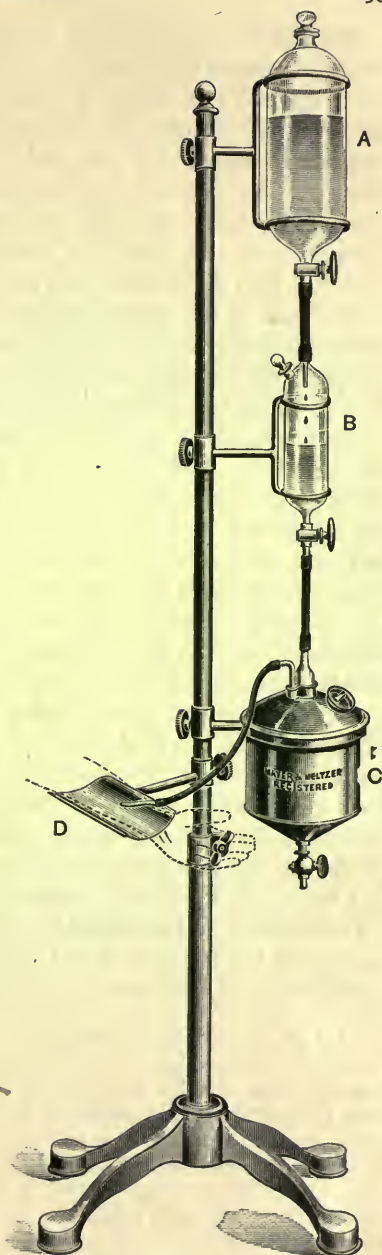
FIG. 49.—Ether-infusion apparatus
of Dr. F. S. Rood.

Technique.—The solution is prepared by shaking ether in sterilised normal saline until it is thoroughly dissolved. Saline * takes up 10·8 per cent. by volume of ether, but a 5 per cent. ether solution is the best for ordinary use, although it is permissible to use a 7·5 per cent. after induction by the lower strength. Some of the earlier workers employed a 10 per cent., and I have done so myself, with the result that hæmolysis has occurred ; in this case the urine will contain blood-colouring matter. This is probably due to destruction of the erythrocytes in the vein in the immediate neighbourhood of the cannula, as when the ether solution is diffused through the blood stream it is rapidly diluted to a safe strength, especially so if the operation is in progress and hæmorrhage is occurring.

The whole of the apparatus is sterilised by boiling, and is then put together. The reservoir is nearly filled with the solution and a gauze cap laid over its inlet to keep off dust, the reservoir tap is opened, and the regulating chamber filled half with air and half with solution, as already described. The regulating-chamber tap is now opened and a continuous flow allowed through the warming chamber until this last has been freed of air. Some ether will volatilise and bubble up, but this is of no importance, as it is reabsorbed and so cannot enter the vein. When the whole apparatus is free of air and full of saline-ether solution the regulating-chamber tap is closed, and as soon as the air in it is compressed to its limit the flow from the reservoir will cease. If it does not, this will be due to some leakage-out of air which must be sought for and prevented. The warming chamber (C) is now placed in the hot-water receptacle and the cannula and tube laid in a dish containing sterilised water.

Preparation of the patient. — It is advisable to prepare the patient in the usual way and to give a hypodermic injection of morphine gr. $\frac{1}{6}$, scopolamine gr. $\frac{1}{100}$, and atropine gr. $\frac{1}{100}$, one

* Mr. R. R. Bennett (*Pharm. Jour. and Pharmacist*, Aug. 3, 1912) has conducted an investigation into the solubility of ether in normal saline. Normal saline solution (isotonic) is prepared as follows : 0·91 grm. of pure sodium chloride is dissolved in 99·09 grammes of freshly distilled water, filtered, and boiled for half an hour. During the collection of the distilled water and the filtration, exposure to air must as far as possible be avoided. The average number of grammes of purified ether prepared from methylated spirit, soluble in 100 grms. of normal saline at temperatures between 0° C. and 30° C., is—0° C., 13·46 ; 5°, 11·55 ; 10°, 9·87 ; 15°, 8·50 ; 20°, 7·38 ; 25°, 6·46 ; 30°, 5·83.

PLATE IV.
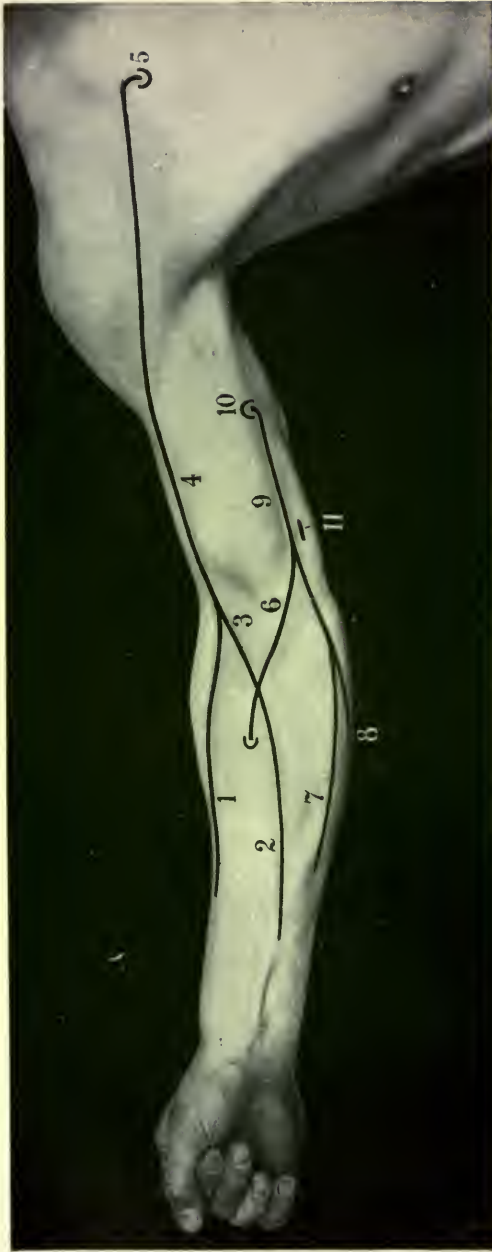
3. The median-cephalic vein.
4. The cephalic vein.

5. The point at which the cephalic vein
   pierces the costa-coracoid membrane.
6. The median-basilic vein.

9. The basilic vein.
10. The point at which the basilic vein
    pierces the deep fascia.

The position of the cephalic and median basilic veins is shown. Into the larger of these the cannula is inserted.

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hour before the infusion is to be made. The doses of these may vary with the individual patients. As a rule the arm is the best limb to select for the infusion, as the leg veins are less easily manipulated and are farthest from the head, a disadvantage since it is necessary for the anæsthetist to be able to prevent mechanical interference with respiration due to falling back of the tongue, dropping the jaw, and so on. The arm selected should be that farthest away from the place where the operator will stand during the operation. The next thing is to carefully cleanse the bend of the elbow and paint it with a preparation of iodine. The larger of the two veins—the median basilic or the cephalic—should be selected, and, unless it is large and stands out well, being uncovered by loose fat, its course had better be marked with nitrate of silver (see Plate IV). The area in which the vein will be opened is now infiltrated with benzamine (β-eucaine) solution, care being taken to introduce the solution below the vein as well as in its periphery. After a few minutes the œdema disappears and the line of the vein is fairly evident. If it is not visible the patient should grasp a stick in his hand and a fillet should be tied round the arm some way above the elbow. The arm is now placed on the arm-rest (D) covered by a sterilised towel and secured in position with a bandage fixed below and above the elbow. A slanting incision across the line of the vein is then made and the vein defined and cleaned. Two ligatures are passed round it ; of these the peripheral one is tied. The cannula and rubber tubing are now fitted to the egress tube of the ether-saline solution and some solution allowed to flow through the cannula to remove all air in order that as soon as an incision is made in the vein the cannula can be introduced and tied in. The danger of its slipping out is in this way prevented. Some surgeons have adopted the use of a metal cannula such as is used for salvarsan injection, plunging this into the vein without any preliminary dissection. My experience is not in favour of this procedure, as it is often difficult to avoid going right through the vein and infiltrating the tissues ; besides which the trauma which occurs with this method seems more severe than that due to a deliberate dissection. The few minutes saved are really of no moment in the case of a drugged patient whose arm is analgesic, and when neither sedative drug nor analgesic is employed the pain inflicted by the stab of a sharp cannula seems hardly justifiable unless a very definite counter-

balancing benefit accrues from the procedure. The rate of flow
is controlled by opening or partly closing the regulating chamber,
and the anæsthetist, by watching the flow or dropping from the
reservoir into the regulating chamber, can gauge quite accurately
the amount of fluid passing into the vein.

Administration.—The above preliminaries having been carried
out, the administrator steadies the arm and removes the con-
stricting fillet. He should notice whether the flow continues,
and, if it does not, he should ease the cannula and correct any
flexion at the elbow or kink in the tubes. Full flow should be
permitted at first, and in a minute or so the patient's breath will
smell of ether. Muscular subjects may struggle and bend the
arm, thus causing back pressure and forcing blood into the
warming chamber, but usually by keeping the arm firmly on
the rest this can be prevented or corrected, and the flow goes on,
when anæsthesia rapidly occurs. If the cannula is forced out,
the vein must be at once compressed above the opening into it,
and the cannula re-entered and secured more efficiently. When
anæsthesia is present the supply of ether is lessened by partly
closing the tap from the regulating chamber, but cessation of
flow must never be allowed, lest clotting in the cannula occur,
an event not devoid of danger. As the operation goes on, con-
stant modifications in the rate of flow will be called for, but
experience will enable the administrator to regulate the degree
of narcosis with great accuracy. A slight excess of ether often
causes cyanosis, especially if the jaw is allowed to drop, and
cessation of respiration is not uncommon. This symptom, which
may appear alarming, need not be so, for a lessening of the ether-
supply and a gentle pressure on the ribs will at once restart
breathing. It need hardly be pointed out that the utmost vigi-
lance is necessary, as, although the danger is trivial if at once
noticed and dealt with, it may become most serious if neglected.
Muscular, vigorous persons upon whom a difficult dissecting
operation has to be performed, _e.g._ one on the abdomen, may
need a higher percentage of ether, but this is very seldom the
case, and if the necessity arises it is a very simple matter for
an assistant to add more ether saline solution to the reservoir,
increasing the strength of the solution. If the solution has been
made stronger, it should be again lessened in strength as soon
as possible. It is essential also, as far as the exigencies of the
case permit, to limit the amount of fluid introduced. Koenig

and others have asserted that fatal accidents have resulted from excessive quantities of saline entering the circulation and causing œdema of the viscera or effusion into the large serous cavities. Upon the other hand, a moderate quantity of saline exercises some influence in the direction of lessening collapse. Probably the slowness of introduction is a safeguard when the flow is continuous. It has been shown that saline solution rapidly leaves the blood-vessels, and Prof. Bayliss has proved that the addition of gum acacia prevents this, so that the question arises whether the Bayliss gum saline * would not be a better vehicle for the ether than that now employed. I have not, however, had an opportunity of putting this suggestion to the test of experiment. Anæsthesia is usually induced ·without struggling or discomfort, is light in character, and the patient resumes consciousness within a few moments after cutting off the ether solution. As soon as the operation is seen to be nearly over, the ether infusion should be materially lessened, and when it is completed the vein must be secured with clamp forceps and the cannula withdrawn. The vein is now completely severed, and the proximal as well as the distal ends carefully secured with ligatures so placed that the portion of the vein which has been subjected to injury can be cut away. The wound, which should have been kept moist and sterile during the operation by a pledget of sterilised gauze wetted with saline, is irrigated with saline and the requisite stitches inserted and a dressing applied. If cleanliness has been properly seen to and the vein has not been damaged during efforts to insert the cannula, there is little fear of local trouble.

After-effects.—Those usually associated with ether inhalation may occur, but their incidence is probably less in intravascular infusion. Vomiting and pulmonary complications are rare, but both may arise. Albuminuria, with hæmoglobinuria, due to over-concentration of the solution, and subcutaneous hæmorrhages, have been seen. A severe attack of jaundice followed in one of my cases, but it was impossible to say whether the ether had any causal relation with the symptom. The patient was otherwise none the worse, and the jaundice soon disappeared. Thrombosis, air embolism, phlebitis, and plugging of vessels by thrombosis have all been reported, and although most of these

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* Six grms. of selected clean tears of pure gum dissolved in the normal saline solution filtered and sterilised by boiling (6%).

dangers can be avoided by an accurate technique and experience of the method, they have to be reckoned with, especially when unsuitable patients are so treated, or the administrator has little experience of the method. The knowledge of about five hundred cases induces Dr. Rood to regard the method as comparing very favourably in the point of view of safety with others, and my own observation certainly bears out this contention.

Suitable cases.—The type of patient which suggests saline infusion to stave off shock is peculiarly appropriate for intravenous etherisation. Abdominal sections, especially in acute cases, extensive operations about the upper air-passages, are all suitable. The young and the aged lend themselves equally to it if due care is taken to limit the amount infused to the capacity of the patient. I have not adopted this method in the case of young children.

When the field of operation involves the mouth, pharynx, or larynx the anæsthetist must keep control of the head, to prevent blood being aspirated into the air-passages ; respiration must be watched to prevent its being hampered by backward displacement of the tongue.

INTRAVENOUS INFUSION OF HEDONAL.

Federoff and Jeremitsch, having satisfied themselves by experiment upon animals, adopted the use of hedonal, methyl-propyl-carbonal-methane ($NH_2.CO.O.C.H.CH_3.C_3H_7$), as an anæsthetic for man. They employed an interrupted infusion method, a 0·75 per cent. in normal saline being injected under air-pressure. The needle was inserted into a superficial vein and sufficient of the hedonal solution injected to produce anæsthesia; the needle was then withdrawn and reinserted if a prolonged anæsthesia was necessary. The results obtained were on the whole satisfactory, but less so when leg veins were injected. Respiratory trouble occurred.

Mr. C. M. Page,* whose apparatus for intravenous infusion of hedonal has been modified by Dr. Z. Mennell, has used this means of obtaining anæsthesia in a number of cases at St. Thomas' Hospital, and regards it as valuable, but cautions against its employment in unsuitable cases.

* *Proc. Roy. Soc. Med.*, sect. " Anæsthetics," 1912, vol. v. pt. I. p. 84. Mr. Page gives a useful résumé of the subject, and the author is greatly indebted to him for his kindness in supplying information.

Hedonal is a white crystalline solid, stable at ordinary temperatures. It dissolves in water at 100° F. to 1 per cent., and is unchanged by boiling. It produces some fall in blood-pressure; in toxic doses the vaso-motor centre is paralysed. Cyanosis is apt to appear, and respiration is slowed.

The solution is made by dissolving hedonal in sterile saline at 75° F., 0·75% strength being employed. This is filtered, boiled for five minutes, and stored in sterile flasks.* It is heated to 105° or 110° F., as higher temperatures lead to local thrombosis. Mr. Page adopts a continuous infusion, and finds 500 c.c. is an average amount per patient. The induction period is 2 to 13 minutes, and the narcotic effect of the hedonal persists for a long time after infusion has ceased. Muscular relaxation is satisfactory. There is a fall of blood-pressure and some cyanosis; this latter is commonly due to the tendency of the tongue to fall back unless closely watched, or fixed so that it cannot occlude the glottis.

Post-operative effects.—Mr. Page points out as a possible danger the onset of cyanosis, and Federoff records some instances of temporary cessation of respiration. There is

Fig. 50.—Mr. Page's hedonal infusion apparatus.

danger of vomitus or blood entering the air-ways during the post-

* Hedonal crystallises out of its solution on cooling. It may be kept for some weeks and redissolved preparatory to injection.

operation profound sleep, since this coma may last for six to twelve hours.   In a few cases emotional manifestations occurred ; in some headache.   In three cases there was some local thrombosis. No hæmolysis was observed.

Contra-indications.—The method is unsuitable for cases in which pulmonary engorgement or a gross cardiac lesion exists ; for operations on the air-passages ; also for patients with high blood-pressure.

Dangers.—The experience of the last few years has confirmed Prof. Burkhardt's view of the danger of hedonal.   Not only have the gravest complications arisen during its administration, but deaths have resulted from its use.

A discussion on the use of hedonal * held before the Medical Society of London provoked somewhat diverse views, but the consensus of opinion was against the use of the method.

Isopral has not been extensively used in this country, so it is impossible to gauge its value, but it must be admitted that neither this substance nor hedonal is so safe as ether for intravenous infusion, and their use had better be avoided.

D. Rectal Etherisation—Colonic Anæsthetisation.

Pirogoff and Roux as early as 1847 suggested that ether should be given by the rectum, and finding that liquid ether could not be injected with impunity (Magendie), the former employed an apparatus which permitted only ether vapour to enter.   Pirogoff obtained such good results that he believed rectal etherisation would replace pulmonary inhalation.   More recently Dr. Axel Yversen of Copenhagen, Dr. O. Wanscher of the same city, and Dr. Mollière of Lyons, as well as Drs. Bull and Weir of New York, tried rectal etherisation, and spoke in favourable terms of it.

I have used the method extensively since 1885, and have found it to answer admirably for operations about the mouth, nose, and post-buccal cavities, for intra- and extra-laryngeal operations, for staphylorrhaphy and for operations for the relief of empyema.   For the removal of the tongue, for excision of the jaw or jaws, and for plastic operations about the face, the method gives great facilities and freedom to the operator.   Mr. Appleby recommends the method also for prolonged dental operations.

* *Trans. Med. Soc.*, Oct. 28, 1912.

The advantages claimed are (i.) less ether is used, (ii.) recovery is more rapid, (iii.) after-effects are less severe, (iv.) the stage of excitement is lessened or abrogated.

More recent advances in the technique of anæsthesia such as dosimetric methods of chloroform administration, and the intra-tracheal and intravenous plans of introducing ether, have at the present time removed many of the difficulties in dealing with anæsthesia in oro-nasal and laryngeal operations, so that the rectal route has lost some of its claims for adoption in these cases. It remains, however, as a valuable alternative for some patients for whom other methods are open to serious objection.

Its disadvantage is—the greater length of time the patient usually takes to become ready for operation. Although this objection is not applicable to all cases, I have found it expedient to shorten the time of induction by giving ether or chloroform in the usual manner through the air-passages, trusting to rectal etherisation for the maintenance of anæsthesia. Besides saving time, this plan lessens the actual quantity of ether required, and so minimises the chance of deleterious after-effects, and also preserves the patient from the discomforts of the induction when performed by rectal etherisation. Dr. Wanscher, how-ever, says some of his patients, having been anæsthetised first by the usual method and subsequently by the rectum, preferred the latter. Dr. Bernard Stedman employed rectal etherisation in a series of cases adopting my method, and has reported most favourably upon it.

In some instances severe meteorism, diarrhœa, and even melæna, have resulted, although not in my own cases. Un-questionably the method requires the greatest care and some experience before a uniformly happy result can be expected, and the anæsthetist must remember that carelessness in permitting too rapid an evolution of the vapour will lead to grave suffering if not to danger and death. I am inclined to believe that the simple method which I employed, safeguarded by the intercepter, to the use of which I attach great importance, avoids many risks which attend the employment of a plenum system with its danger of distension of the bowel. How real is this peril is shown by the fact which Dr. Sutton * points out, that the vessels of the gut become ischæmic from stretching of the muscular coat of the intestine, so that no absorption can take place until the

* See Gwathmey's " Anæsthesia," 1914, p. 433.

pressure is relieved, when rapid absorption occurs, and the narcosis is deepened, it may be to an undesirable degree.

The **apparatus** I have employed is in effect an ether receiver holding about 2 or 3 ounces ; this is plunged into a second vessel which should contain water at 120° F.   The ether vial communicates by an indiarubber tube with a glass intercepter devised to prevent the entrance of liquid ether into the rectum.   The farther end of the intercepter is joined by another and shorter
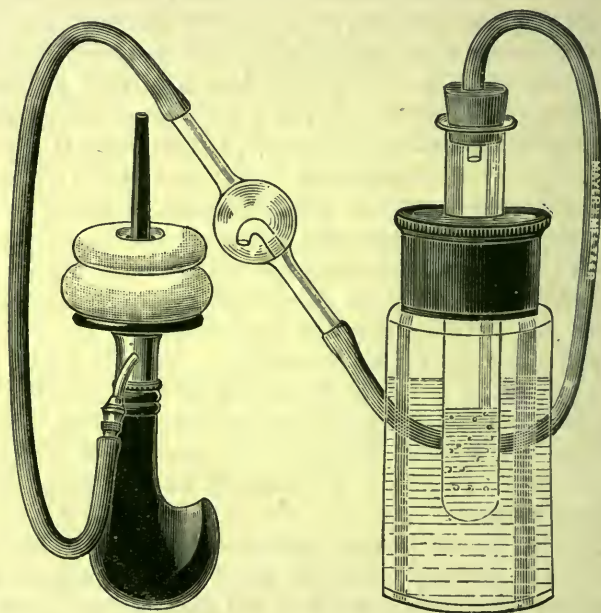
FIG. 51.—Dr. Dudley Buxton's apparatus for administering ether per rectum.

tube to an anal tube.   This is made for me by Messrs. Mayer and Phelps.   Some persons have employed the water at a higher temperature, but my experience leads me to believe that the untoward experiences which have been recorded have in most, if not all, cases been brought about by having the water too hot, and so permitting a too rapid evolution of ether vapour.

The use of my intercepting drip chamber is of great importance as it catches any condensed ether vapour, and prevents the passage of liquid ether into the bowel.   This apparatus has

been copied by various persons, and they have, by omitting this drip chamber, vitiated the whole apparatus, and rendered their patients liable to proctitis and other dangers.

The usual signs of anæsthesia are present, and so nothing need be said about them. As a rule children go under more rapidly than adults, when ether is given by the rectum, but the time occupied in inducing complete anæsthesia varies within wide limits. I have succeeded in 3 minutes and have had to wait 15 or 30 minutes. Dr. Stimson informs me that American surgeons have had several fatalities in employing this method. I have met with grave complications in a few cases which, although in part due to the physical condition of the patients, were undoubtedly not wholly independent of the irritation caused in the intestines by the entrance of ether vapour. In no case when using this method have I met with a fatality, and the complications to which I have referred were such as might in most cases have occurred with other methods of producing anæsthesia.

A fatality which occurred some hours after the performance of laryngectomy when the rectal method was carried out by me was believed to have been the result of the ether. The death, however, was one due to sudden heart failure from collapse, and presented none of the symptoms usual when rectal etherisation causes death. As no autopsy was performed it was impossible to prove the actual cause of death. As a rule fatalities, unless due to rapid paralytic distension or rupture of the large intestine, do not occur suddenly.

.The administration.—The actual steps to be taken after anæsthesia is produced by inhalation are simple, although the management of the case imposes upon the administrator the necessity for great vigilance and judgment to avoid the undesirable extremes of too much or too little ether vapour finding its way into the bowel. There are certain important preliminaries to the method. The colon must be carefully emptied and prepared by large enemas for some days before the operation ; a hypodermic of morphine and atropine alone or. with scopolamine should be given one hour and a half before the operation. Whether anæsthesia had been produced by the oro-nasal route or not, the rectal tube is gently inserted and the warmed ether vapour allowed to bubble into the bowel. The rubber pad is kept pressed firmly against the perineum by a diaper, but, as one of the first effects of the ether is often to cause an accumulation of

flatus in the lower colon, it is wise to partly withdraw the tube and allow the gas to escape. I have had an escape tube introduced into the apparatus to facilitate this escape without disturbing the apparatus, but this is not shown in the figure. A tap operates this exit tube. As a rule little struggling occurs, and if present is easily controlled. When the mucous membrane of the bowel is accustomed to the ether, the amount of anæsthetic can be increased. The breath of the patient will smell of ether within a minute or two of the commencement of the procedure. As soon as complete anæsthesia is present, the amount of ether is to be lessened. This is done by lifting the ether container out of the water chamber.

The water chamber must from time to time be refilled, as the water soon cools. It is wise to palpate the abdomen occasionally, and if undue distension occurs the supply of ether must be checked and any rectal flatus allowed to escape. Dr. Cunningham * and Dr. Dumont of Berne, the latter of whom has adopted my apparatus, have advocated the method and have met with success in its application. The former's procedure differs from mine. He drives air through ether and introduces the mixture into the bowel. When a plenum system is adopted there is much greater danger of distending the bowel and causing deleterious results unless a free escape of the vapour is provided. Dr. Thomas of Yale has proposed a double current, one of ingress and one of egress, to avoid this danger. However, if the bowel passes into paralytic distension there is no expulsive power to cause a return of the injected gases, and the ether vapour passes higher up the colon. Dr. Sutton † in an able paper points this out, and insists upon the precaution being taken of emptying the rectum every five or ten minutes to expel natural flatus and excess of injected air and ether vapour. Further excess of pressure, *i.e.* above 20 mm. Hg, must be avoided, and some recent apparatus have a manometer in their circuit to enable the anæsthetist to avoid this danger. It may be pointed out that, by a very simple development of the apparatus figured, an electric warmer can be added, thus enabling the anæsthetist to control by a switch the temperature of the water in the warming chamber.

After-effects.—Colicky pains in the intestines, urgent tenesmus, diarrhœa, sometimes dysenteric in character, painful distension

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* *Boston Med. and Surg. Jour.*, April 20, 1905.
† *Op. cit.*

of the intestinal tract with more or less severe collapse, are the complications which have been recorded.

The treatment is to be conducted upon general principles, opium forming the most useful therapeutic ally. For their prevention the most important points needing attention are avoidance of the method in cases with a history of previous intestinal catarrh or dysenteric attacks, and great care that during the administration no liquid ether is allowed to enter the rectum.

COLONIC ETHERISATION.

Dr. Arnd has adopted the method of introducing, per rectum, a stream of a 5 per cent. solution of ether in warmed saline, and my friend Mr. Flemming, of Bristol, has tried this plan with some success. A preliminary hypodermic injection of alkaloids is given. In Arnd's cases diarrhœa followed the procedure, but the stools were free from blood. I cannot speak from any personal experience of this plan, but my knowledge of the vapour method would cause me to be disinclined to introduce ether into the bowel in a liquid solution. Further evidence may prove this criticism to be based on incomplete knowledge.

THE OIL AND ETHER METHOD.

Dr. Gwathmey, as a result of some very interesting experiments, has shown that if ether is mixed with oil (carron oil is best) in a proportion of 50 per cent. and introduced into the bowel by means of a catheter, anæsthesia results. For human beings he used at first a 75 per cent. of ether.

Gwathmey's method * has now been extensively used both in the United States and in this country. During the war it was tried and in most cases found to be a valuable plan in the case of operations upon the face, jaws, and neck. The PREPARATION of the patient is most important. A massive dose of castor oil is administered on the night before the operation, and hourly enemata are given in the morning until the return is colourless. The patient then rests for three hours. It should be remembered that enemata may cause faintness, and so the patient must be

* This system of anæsthetisation is fully described in Dr. Gwathmey's book " Anæsthesia," 1914, pp. 458–66.

carefully watched. Chloretone (5 gr. to 20 gr.) or paraldehyde ($\mathfrak{Z}$ii.–$\mathfrak{Z}$iv.) or isopral may be used, mixed with four ounces of ether and four of olive oil, and injected per rectum; this is followed in half an hour by a hypodermic injection of morphine (gr. $\frac{1}{6}$) and atropine (gr. $\frac{1}{200}$—$\frac{1}{100}$). If the patient is athletic or alcoholic, Gwathmey uses scopolamine one dose (gr. $\frac{1}{100}$) two hours before and a second gr. $\frac{1}{100}$ with morphine gr. $\frac{1}{4}$ one hour before the operation. The patient is kept absolutely quiet and lies in bed upon his left side, and the rectal injections are given very slowly. The mixture when first employed consisted of 50 to 65 per cent. of ether in olive oil for children, for whom no preliminary medication is advisable, and for weakly anæmic persons, and 75 per cent. ether for normal adults. However, a 75 per cent. sometimes causes interference with respiration, and may be occasionally followed by some unpleasant effects. Dr. Gwathmey now advises a maximum strength of 65 per cent. ether and a maximum dose of 8 ounces of the mixture. With this amount as a maximum, he suggests that the dose should be, for adults, 1 ounce for each twenty pounds body weight. A rectal tube is introduced into the bowel and connected by rubber tubing with a funnel, and into this the solution is poured. The funnel is raised and the mixture slowly enters the bowel, one minute being allowed for the entry of each ounce. When the injection is completed the patient remains quiet for twenty minutes, and then, if he is anæsthetic, he is removed to the operation table and the surgeon commences his work. The depth of narcosis is gauged by (i.) loss of lid reflex, (ii.) cyanosis, (iii.) stertor, and when these occur the mixture is withdrawn from the bowel. To facilitate this, Dr. Shipway advises that an outlet tube should be kept in the rectum and its external end secured by a clip. The clip can be loosened in a moment and some or all of the mixture allowed to run out. If this measure fails to lighten the narcosis and respiration becomes hampered, a Connell's breathing tube should be introduced or artificial respiration commenced. Gwathmey also recommends, when the patient's condition appears to be desperate, that 1,000 c.c. or 2,000 c.c. of normal saline should be introduced into a vein. Probably Bayliss' gum solution would prove more effectual than the saline (*vide infra*). In cases of respiratory failure Gwathmey suggests that carbon dioxide should be administered with the view of stimulating the respiratory centre. Whether this procedure is

of much value modern views on the acapnia theory would seem
to throw some doubt. It is probable that deficiency of oxygen
rather than of carbon dioxide is the *causa causans* of the trouble.
If, as sometimes happens, the narcosis becomes too light, through
over-distension of the bowel or excessive lung ventilation, the
patient's face should be covered with a towel to induce rebreath-
ing and to prevent undue elimination from the lungs. Failing
this, naso-oral administration of an anæsthetic must be adopted
for a minute or so. The duration of anæsthesia following the
injection of 8 ounces of the mixture and the preliminary
drugging is said to be from two and a half to three hours.

Captain J. C. Clayton * has found this method satisfactory
in the case of soldiers. He combines the paraldehyde with the
ether-oil solution, thus obviating the preliminary injection, and
adopts rebreathing during the induction. He ignores the
patient's weight, and judges the dose by physical fitness or the
reverse, and restricts the dose to 5 or 6 ounces. The solution
Captain Clayton adopts is composed of ether ʒv.–vi., olive oil ʒii.,
paraldehyde ʒii., or chloretone gr. 30. In one of his cases artificial
respiration had to be practised for two and a half hours. Preli-
minary hypodermic injections of morphine, atropine, and some-
times scopolamine, were employed. Mr. H. M. Page has adopted
this method, using a solution of ether ʒiv. in oil ʒii., and he
claims good results and no undesirable after-effects.

AFTER-TREATMENT.—The solution is drawn off by a rectal
tube, and the bowel irrigated by double tubes, one admitting
and one withdrawing soap solution or saline. This should be
followed by an injection of 5 ounces of olive oil.

The method is no doubt a valuable one, but its technique is
somewhat complicated, involving much time, and calls for con-
siderable judgment and experience. Cases have been mentioned
in which some difficulty has been experienced in awakening
patients from their post-anæsthetic stupor and in restarting re-
spiration. Diarrhœa, proctitis, melæna and anal soreness have
occurred, but Dr. Gwathmey's experience leads him to believe
such sequelæ are rare, and when they arise are due to errors of
technique. It is obvious that much care is required in watching
a patient who has been given simultaneously several powerful
drugs, in the present case atropine, morphine, sometimes scopol-
amine, chloretone, with or without paraldehyde and ether.

* *Lancet*, May 10, 1919.

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E. Intramuscular Injections of Ether.

Walther * has attempted to anæsthetise patients by injecting
ether into their buttocks.   He used 0·45 c.c. up to 0·8 c.c., and
states he obtained satisfactory results.   An anæsthetic given
by inhalation was used to hasten the effect.   Slight convulsion
and ecchymosis followed the injection. Dr. Descarpentries
speaks favourably of this procedure, although his experience
is at present limited.   Other observers who have tried the
method have failed to obtain anæsthesia, although very large
quantities of the anæsthetic were injected; further, the injection
has caused abscess, so that one can hardly recommend this pro-
cedure.

F. By the Mouth.

Gwathmey and H. T. Karner † report the use of paraldehyde
1 fld. drachm, ether 3 fld. drachms, and liquid petrolatum
4 drachms, given by the mouth for cases such as painful dressing
of wounds, fractures, and so on, and extol the method.

Complications during Ether Narcosis.

The chief complications are connected with respiration.   In
the first place in persons whose lower jaw is underhung the
mandible with the tongue is liable to fall back and so interfere
with respiration.   The fingers placed behind the angles of the
jaw will readily rectify this, but it is important to see that the
lower teeth are not engaged behind the upper, but project well
beyond them in front ; to effect this the mouth must be opened
and the jaw pushed forward, and when the lower teeth have
advanced in front of the upper the mandible is kept in that
position.   The breathing may be stopped by a more serious cause
through obstruction in the larynx, the rima glottidis becoming
closed and no air entering the lungs.   In some cases the rigidity
of the masseter muscles may cause impediment to air entry by
provoking tight closure of the teeth.   Inspiration through the
nose is very commonly imperfect through some stenotic con-
dition, and it may be greatly hindered or prevented by the
nostrils being sucked in with inspiration, whilst the lips at the

* *Bull. Medical,* May 29, 1912.
† *Brit. Med. Journ.,* March 13, 1918 ; *Journ. of Amer. Med. Assoc ,*
April 6, 1918.

same time are drawn in over the clenched teeth. In this way little air can enter the chest and the patient becomes cyanosed. If the teeth be forcibly separated by a mouth-opener, air will enter freely and the cyanosis pass off. It is wise in these cases to insert a gag between the teeth before replacing the inhaler. The employment of the artificial air-way tube is of value in such cases, especially if the patient is edentulous and has powerful muscular lips. Should too much air enter, a towel can be wrapped around the face-piece. Laryngeal spasm,* leading to partial or complete closure of the rima glottidis, may arise ; it is in most cases due to the impact of too concentrated ether vapour upon the sensitive laryngeal mucous membrane, but is especially liable to occur if cyanosis has been allowed to arise. In cases in which the trachea is displaced or pressed upon by inflammatory swelling, such as in angina Ludovici, or by morbid growths such as goitres or masses of lymphadenomatous glands, if ether is incautiously given, laryngeal spasm and asphyxia are peculiarly likely to occur. Intubation, if possible, or perflation with oxygen offers about the only means available in such cases. Laryngeal spasm more commonly occurs when there is pre-existing hyperæsthesia of the mucous membrane, *e.g.* in inflammatory conditions and in the case of heavy smokers. Commonly the spasm is initiated by an attack of coughing, then the inspiration becomes stridulous and the patient grows cyanotic. It is usually sufficient to withdraw the ether until the spasm passes off and then administer the anæsthetic more guardedly. In very extreme cases it might be necessary to perform laryngotomy. The danger is accentuated in short, thick-necked persons, and in those who, through inflammatory or other causes, suffer from pressure upon the trachea. In one case of which I have notes, laryngotomy was actually commenced, but fortunately I was able to force oxygen into the lungs and normal respiration was restored. Chloroform was then substituted for ether. In this case there was no reason to believe that ether would prove an undesirable anæsthetic. The movements of respiration do not cease in the condition of laryngeal spasm, but are exaggerated.

In edentulous persons the long flabby lips are sucked in and act as a kind of valve permitting expiration but hindering inspiration. To remedy this the jaws should be separated by a

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* In angio-neurotic œdema the larynx may become suddenly occluded. (See Chap. X.)

Ferguson's gag ; it is then easy to administer the ether, as the gag keeps the mouth open and the lips apart. In figs. 52 and 53 is shown a device for use in edentulous cases. The metal end E is placed between the gums in the front of the mouth, and the rubber tube passes over the tongue to the region of the epiglottis. This contrivance maintains a patent air-way in such cases, but unless great care is taken the rubber tube is liable to get out of position and so become useless. Some anæsthetists insert a dental prop between the teeth before giving the anæsthetic, and find it prevents some of the complications referred to above.
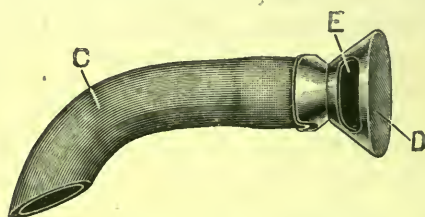
FIG. 52.—Mouth tube for edentulous cases.*
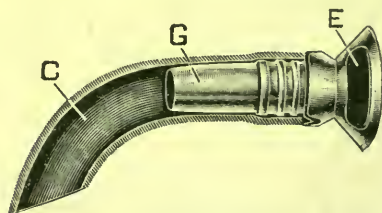
FIG. 53.—Section of mouth tube.*

This procedure is not appreciated by the patient and is not necessary except in a few cases.

A more troublesome, although fortunately rare, complication occurs when the thorax becomes fixed by spasmodic contraction of the muscles of respiration. The treatment here is to maintain the air-way patent, and to attempt to overcome spasm by artificial respiration. Jerking up the chin will, by dragging the larynx upwards and forwards, often induce the patient to take a deep inspiration. In spasmodic fixation of the thorax, abdominal

* I am indebted to Dr. Ferguson of East Orange for these figures of his modification of Sir F. Hewitt's mouth tube. Dr. Silk has introduced a nasal tube which ensures a free nasal passage.

respiration must be practised, and the floating ribs compressed in expiration. Stimulation of the nasal mucous membrane will sometimes initiate a deep inspiration. This can be done with quills of bibulous paper soaked in sal volatile or a weak ammoniacal solution. Laborde's plan of rhythmic traction upon the tongue twenty times in a minute will prove valuable if the above fails. Freudenthal * suggests direct irritation of the epiglottis, and avers this gives better results than Laborde's plan.

When a slight degree of spasm of this kind follows coughing and irregular breathing, replacing the ether by chloroform for a few respirations will often completely remove all trouble. In all conditions the danger is increased by the rapidly deepening cyanosis. If the air-way can be rendered patent—and this usually can be accomplished by the means mentioned above— oxygen given under pressure, as from a cylinder of compressed gas, will greatly facilitate recovery. Intubation and perflation with oxygen are practically always possible, and seldom, if ever, fail to restore the function of respiration.

Mucus, or excessive salivary secretion, by collecting about the epiglottis and laryngeal chink, sometimes sets up spasm and considerably interferes with respiration. I have met with one case in which a brief administration of ether for examination led to a most dangerous condition owing to the large amount of fluid secreted in the air-passages. Inversion, tongue-traction and mopping out the pharynx eventually removed the obstruction to respiration and terminated successfully what was a most alarming experience. Such cases emphasise the value of the plan I now invariably adopt of injecting atropine an hour before administering ether. The same danger may arise from some blood effused during the operation, or from epistaxis, and these conditions must be borne in mind. Hæmoptysis and hæmatemesis are less liable to occur during the administration of ether than afterwards, but I have met with the former condition more than once. Placing the head well over to the side and sponging out the pharynx usually remove both the dyspnœa and its cause. Epistaxis may occur especially in the young and in adults with unduly high blood-pressure, and unless this complication is noticed, the blood-clot will impair respiration. In persons whose faucial isthmus is narrowed, and in those whose respiration under ether is not free, the tongue is liable to grow congested, venous

* See *New York Medical Journal*, Dec. 10, 1898.

return being hampered, and the swelling thus caused becomes a
further factor in interfering with breathing.   Opening the
mouth, drawing the tongue forwards, and maintaining an
adequate supply. of air or oxygen will usually remove these
difficulties.

Less important inconveniences of ether inhalation are the
increased secretion from the mouth and respiratory tract ; these,
although interfering with respiration, are seldom of any great
importance.   Hölscher * has pointed out that râles heard in the
trachea are due not to the secretion arising from irritation of
the broncho-tracheal mucous membrane, but to aspiration of
mucus and saliva from the mouth.   It must be remembered,
however, that in infants and weakly persons this excessive
secretion may prove a grave complication, and cause blocking
of the tubes and water-logging of the lungs.

Coughing occurs in many persons, especially if ether vapour
be given in too concentrated a form ; but it is not always neces-
sary to remove the inhaler or mask to remedy this, for frequently,
while a dry cough comes on in the earlier stages of etherisation,
it is suppressed by pushing the anæsthetic.   I have met with
some cases in which cough has been very urgent, and associated
with inspiratory dyspnœa and cyanosis so severe as to be alarm-
ing.   In such cases some spasm usually exists.   Inhaling oxygen
will as a rule completely and rapidly remedy this condition, or a
few whiffs of chloroform may be given.   Such complications
as laryngeal spasm and coughing are far less prone to occur
when the ether vapour has been sufficiently warmed and
moistened before inhalation.

The danger of **aspirating foreign bodies** into the **air-passages**
is of course present when the patient is under ether just as when
he is under any other anæsthetic, but no detailed notice need be
given here, as this complication is considered at length elsewhere.
A caution may be given about sponges and gauze mops inserted
in the mouth during operations.   These, when full of blood, are
difficult to recognise unless secured by a ligature.   If attention,
however, is paid to the **posture** of the patient, so that the head
is turned to one side, many of the dangers just referred to may
be avoided or minimised.   In the Trendelenburg position patients
under ether often experience some respiratory embarrassment.
They become cyanosed, and œdema of the face, also possibly of

* " Archiv. f. Klin. Chir.," B. 57, 1898.

the larynx, may develop. The posture must be altered and oxygen freely given in order to remedy this complication.

Overdose.—If ether be incautiously pushed for a prolonged period, without allowing the patient from time to time to renew the air in his lungs, the respiration may stop altogether. This condition would appear to ensue upon the overloading of the blood with ether, leading to poisoning of the respiratory centre. The treatment is the cessation of the administration and the immediate performance of artificial respiration. If this be properly done the blood soon becomes duly oxygenated, and the nerve centres, being once more supplied with depurated blood, recover their control over the respiratory mechanism, and so natural respiration ensues. During very prolonged operations it is also wise to give ether sparingly during the last portion of the time, as when once the patient has been thoroughly narcotised by the anæsthetic he will remain unconscious for a considerable time without further inhalation. This is especially true if narcotics such as morphine and scopolamine have been injected previously to the inhalation. Indeed, whenever such drugs have been employed the anæsthetist will have to limit the amount of ether given to avoid overdose—moreover, little is required. When care is taken to prevent the patient growing at all cyanosed, overdosage cannot occur.

The danger incident to **over-stimulation** should always be in the mind of the administrator of ether. The initial effect of ether is to provide stimulation in cases of vital depression or when surgical shock is anticipated, but this stimulation is effected at the cost of still further exhaustion of the nervous system, and unless the amount of stimulation is carefully limited to the recuperative power of the patient profound collapse will ensue as soon as the administration has ceased. The breathing will then be gasping and shallow, often of a Cheyne-Stokes type, and the blood-pressure will fall to a dangerously low level, while the body temperature will be materially depressed. To avoid such contingencies, strict ether limitation must be practised, oxygen given freely, saline infusion practised, and measures adopted to raise and maintain the temperature of the body.

Rarely, the **heart** may give trouble. In a few recorded cases fatal syncope has occurred at the commencement of ether inhalation, but whether such casualties can be justly imputed solely to ether influence is, I think, doubtful. Such cases are

regarded by Professor Yandell Henderson as due to acapnia.*
He thinks the initial fear of the patient caused hyperpnœa; this
produced a lowering of the carbon dioxide pressure in the blood.
Imperfect anæsthesia when this condition is present renders
the patient liable to reflex cardiac inhibition, from which the
heart fails to escape. If the patient struggles, however, as
he is sure to do when the ether is given in too concentrated a
vapour, he is liable to syncope from the strain imposed upon
his heart, and this, I think, is the true cause of such fatalities.

Vomiting during the operation is nearly always due to the
giving of too little ether, if the patient has been properly pre-
pared, and follows upon the partial resumption of consciousness.
The patient will be observed to inspire irregularly, with shallow
breaths, followed now and again by yawning inspirations. This
will be succeeded by efforts at swallowing; rapid and chiefly
abdominal inspirations ensue, and the patient retches and
vomits. He grows pale, and the pulse becomes small, or even
imperceptible, while the breathing grows intensely shallow. Con-
junctival reflex returns just before the vomiting. In treatment,
two indications are now paramount, to get rid of the vomited
matter and to avoid any of it being drawn into the larynx by the
deep inspiration which always follows the act of vomiting;
secondly, to prevent complete return to consciousness. To
obviate these, the patient's head should be turned to one side
without being raised, and all vomit removed with a sponge or
by the finger; the inhaler or mask should be then rapidly re-
applied; if further vomiting occur recourse must be had to
similar manœuvres. But a judicious pushing of the anæsthetic
at the first signs of the onset of vomiting will often, if not always,
prevent the occurrence of sickness. In carrying out this plan
great care must be taken, lest, if it fail and vomiting occur, the
ejected matter should enter the windpipe.† If vomit be drawn
into the trachea, and cannot be coughed up, it may be necessary
to open that tube and take measures for the removal of the

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* It is probable that in the cases to which Dr. Henderson refers, respira-
tory troubles were present, although not recognised, and the heart failure
was secondary to anoxæmia, while the hyperpnœa evidenced asphyxia.

† These rules apply only to patients who have been properly prepared
for the anæsthetic. If it is not known whether the stomach is empty and
vomiting threatens, it is best to encourage the sickness and then wash out
the stomach before resuming the anæsthetisation.

foreign bodies from the air-passage. Aspiration of gastric and intestinal contents in cases of abdominal distension is liable to occur during anæsthesia. Some of the recorded deaths under ether have arisen from this cause, and the greatest care must be taken to avoid this complication by lavage, when that is possible and expedient, or by maintaining a sufficiently light narcosis to ensure the persistence of the laryngeal reflex. The subject is, however, dealt with elsewhere and at greater length.

Ether tremor [clonus] is referred to above. The complication is not common, but I have met with it not infrequently. It occurs somewhat more commonly when ether is given by any open method, and is then more pronounced. Ether clonus, being the result of light narcosis, is remedied when a more profound degree has been obtained. It saves time in the end to cease any surgical procedure, *e.g.* skin disinfection, which may be in progress and push the anæsthetic.

After-effects and Dangers of Ether.

These are **immediate** and **remote.** Ether chills the body, so that when the anæsthesia has to be kept up for any length of time it is advisable to keep the patient well covered up, and to apply hot-water bottles to his feet, thighs, and flanks. The arms and legs may also be bound up in cotton-wool, especially when rectal etherisation is contemplated. The use of a hot-water table for prolonged and grave operations certainly counteracts this danger, as well as the shock. This lowering of body temperature is materially lessened when warmed ether vapour is used for the administration.

The unpleasant taste and smell of ether often hang about a patient for hours. They are best got rid of by fresh air in warm and well-heated rooms in cold weather. The clothes should be changed and the mouth washed out with a solution of chlorate of potash, or other mouth-wash. Whenever practicable a patient should be removed from the room in which the anæsthetic has been given as soon as the operation is completed.*

The **post-operative dangers of ether** when **immediate** are due to:—1. Interference with respiration. 2. Interference with circulation. 3. The occurrence of vomiting.

* A little cotton-wool moistened with essence of bitter orange fixed against the nostrils is also useful.

When **remote** they arise from :—

1. Inflammatory attacks affecting the mucous and serous membranes of the respiratory tract and pleuræ or of the alimentary tract.

2. Failure of the circulation.

3. Rupture of blood-vessels.

4. Renal complications.

5. Gastro-intestinal tract ; persistent vomiting (acidosis).

IMMEDIATE AFTER-EFFECTS.

1. **Respiratory.**—Dyspnœa may arise from the posture in which the patient is placed after being put back to bed. Care should always be taken that the head is so arranged that respiration is unhampered and easy. Also, it must be borne in mind that vomiting may occur, and someone must be at hand to prevent suffocation from aspiration of vomited matter into the trachea. An accumulation of mucus may hamper respiration after ether, for until the patient is sufficiently conscious he will be unable to cough away the cause of obstruction. Hæmoptysis rarely occurs, but I have seen slight cases on several occasions. When morphine or scopolamine or both have been given antecedently to the ether, the post-operative sleep is commonly very deep, the respirations are shallow, and if even slight additional obstruction to breathing arises due to malposition, mucus, blood, or vomit, the patient will, if unnoticed, become suffocated without giving any indication of his danger. The same danger, but more urgent, is present after the use of hedonal.

2. **Circulatory.**—Slight faintness may ensue after lifting the patient back to bed, but I have seldom seen trouble from this cause. In no case must the patient be allowed to sit up for some time after the senses have returned, as fatal syncope has occurred upon the patient sitting up to vomit.

3. **Vomiting** commonly sets in before the patient is fully conscious, but as a rule is slight, and soon passes off. When in bed he should have his head turned to one side. It is exceptional for a patient to vomit more than twice unless food has been taken too soon after the anæsthetic, or the patient has been imperfectly prepared for the operation. As soon as he is sufficiently conscious to swallow, he should be given a good drink of hot water in which has been dissolved bicarbonate of

soda ($\mathfrak{Z}$j to the Oj of water). Dr. Chandler * has pointed out that less sickness after anæsthetics occurs when the patients are placed in an almost sitting position as soon as they are returned to bed,. and in this view I believe he is correct. The raised posture of the head and shoulders also lessens the headache which sometimes follows taking ether.

REMOTE AFTER-EFFECTS.

These arise from irritation of the air-passages, of the gastro-intestinal tract, and of the renal mucous membrane set up by the elimination of the ether.

1. **Respiratory.**—In a certain number of cases such complications occur, but I believe when ether is properly given it is rare to find bronchitis or broncho-pneumonia (so-called ether-pneumonia) following its administration. It has been pointed out that pulmonary complications are most commonly found to arise in cases of abdominal section, and especially when septic conditions exist. In this statement probably lies the explanation of the occurrence of many cases of the so-called ether-pneumonia. Dr. Graham,† as a result of some very interesting experiments, has found that ether, when given freely, produces marked effects on phagocytosis. The power of phagocytosis may be lost for weeks, and consequent dangers ensue. This appears to arise through the avidity of ether for lecithin and other fatty materials. When olive oil is introduced into the rectum as soon as the etherisation is complete, phagocytosis returns within a few hours or so. Dr. Ferguson,‡ whose interesting monograph on the subject should be read, has adopted the plan of injecting olive oil $\mathfrak{Z}$v. (150 c.c.) as a routine measure as soon as an operation under ether has been brought to a conclusion. The infection of the lungs is, according to many observers, due to the aspiration of septic material from the abdomen which has found its way into the air-passages. Hölscher's experiments, referred to above, show that aspiration from the mouth, where the pneumococcus is commonly found, can, quite independently of ether, introduce mucus and saliva into the trachea and bronchi. Whatever be

* " Surgery, Gynæcology, and Obstetrics," vol. iii. p. 580.
† *Jour. of Infectious Diseases*, 1911, vol. viii. p. 14.
‡ " Surgical Anæsthesia in its Relation to Immunity," *New York Med. Jour.*, May 11, 1912.

the true pathogenesis of lung complications following ether
inhalation, two facts are certain. Firstly, broncho-pneumonia
does occur, although much more rarely than is commonly be-
lieved ; and, secondly, complications are less liable to be pro-
duced when the anæsthetist limits the quantity of ether given,
and avoids allowing a large amount of ether to enter the blood.
It must be remembered that in times before anæsthetics were
employed, pneumonia was a comparatively common complication
of operations. And further, as ether is usually selected for
the most desperate cases, it is used in cases in which pneumonia
is most likely to develop. The lessening of phagocytic action
no doubt plays an important part in the genesis of these sequelæ.
It is further essential to remove as far as possible any source of
infection by disinfecting the teeth, the mouth, and the nose
before the operation, and when possible to cleanse the mucous
membrane of the stomach, in cases of disease, by preliminary
lavage with a suitable antiseptic.

A mild attack of bronchitis is a not infrequent after-effect of
ether. I have met with a case of pleurisy with pleuro-pneumonia,
but as the condition was right-sided and occurred subsequently
to an operation for the relief of hepatic abscess it may not have
been due to ether. Bronchitis is especially liable to be caused
in patients who have suffered from that disease previously, and
in my experience seldom starts from ether chilling unless in the
aged and asthenic. The danger of broncho-pneumonia and of
true lobar pneumonia after ether is one about the frequency of
which it is difficult to decide. Mr. Carter Braine * found the
record of only one case of pneumonia in 4,380 administrations
of ether, and in this case blood apparently entered the air-passages
during the operation. In the Report of the British Medical
Association published in 1900 four cases were reported as pneu-
monia in about 6,000 administrations. None of these ended
fatally, and some were trivial and rather instances of bronchitis
than of true lobar pneumonia. I have been told repeatedly of
cases of ether-pneumonia, but upon investigation I have found
them to be merely bronchitis, without any of the clinical aspects
of the graver lesion. On the other hand, Dr. Drummond,† Dr.
McCardie, and others, have published cases of pneumonia which
apparently were due to prolonged etherisation. In a valuable

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* *Trans. Soc. Anæs.*, vol. iii. p. 85.
† *Brit. Med. Jour.*, 1898, vol. ii. p. 939.

discussion * this subject was carefully considered, the consensus of opinion being that true pneumonia is a rare complication of etherisation, provided the method adopted is one which prevents excessive quantities of the anæsthetic being taken. The association of pneumonia after ether with abdominal surgery is obviously one of importance, as the patients in these cases are liable both to auto-infection, and to be placed in an unfavourable condition as regards pulmonary ventilation. If there is much bronchial secretion and the abdomen is tightly bandaged, so that respiratory movements are limited, the secretion cannot be got rid of, and is extremely liable to act as a local irritant. It is, no doubt, this which after prolonged etherisation, especially when the anæsthetic is given freely, causes subsequent pulmonary trouble. I am bound to say that in my own practice I have seen very few really severe pulmonary sequelæ to etherisation, but I have always restricted the quantity of ether employed in prolonged operations, and usually, when the condition of the patient permitted it, changed the anæsthetic to chloroform after half an hour or so. This precaution is especially needful, if the patient shows signs of free bronchial secretion.

It is a significant fact that most of the pulmonary sequelæ of ether occur among hospital patients. Pneumonia seldom follows the inhalation of chloroform, as a recent writer has pointed out, but bronchitis certainly occurs as an after-effect. But even admitting this statement, which probably no experienced anæsthetist will dispute, we are still left with the equally well authenticated fact that, when the patient who has taken ether for a prolonged period is kept free from chills, he seldom if ever suffers from pneumonia. As a practical outcome of the discussion it may be accepted that pneumonia is always a possible, although a rare, after-effect of ether, and this liability must be reckoned with in making the choice of the anæsthetic and of the method of giving it. When the condition of the patient suggests pulmonary susceptibility ether had better be avoided. The use of atropine before giving ether must lessen the risk of post-operative pulmonary complications, if the views given above are correct, and certainly experience has shown that most atropinised patients have less bronchial irritation and less vomiting than those for whom atropine has not been prescribed. Further, Pembrey and Shipway's researches indicate that the employment of warmed

* See *Trans. of Soc. of Anæs.*, vol. iii. pp. 55 and 69.

ether vapour lessens the liability of pneumonia supervening. Dr. Pasteur, in the annual oration before the Medical Society of London,* considered ether-pneumonia, and contended that most of the cases of abdominal operations which showed post-operative lung troubles were not pneumonic, but were examples of " massive collapse " of the lungs due to paralysis of the diaphragm or to other causes. His observations go far to prove that ether-pneumonia is often hurriedly diagnosed from symptoms which are really those incident to another condition.

Another aspect of this subject is the infection of the patient by septic organisms from an ether inhaler. The possibility cannot be doubted when dirty instruments are used. Ether, however, is not favourable to the existence of pathogenic organisms. When an inhaler such as that figured on p. 176 is used, and the parts of the inhaler boiled or sterilised in carbolic acid solution, this source of danger can be absolutely removed.

Although the treatment of these lung complications does not fall within the scope of this book, something may be said about prophylaxis. Bearing in mind that there is always a fall of some degrees of body temperature after taking an anæsthetic, it is most important that the patient should be warmly clad and that the room in which he is operated upon be kept at a proper temperature. Not less necessary is it that after the operation he should be always well covered up and carried into a room also heated, and care be taken that he is not chilled during the passage from one room to the other. Many persons lose their lives for want of this obvious precaution.

Acute œdema of the **larynx** and **œdema** of the **lungs** are both complications which have been described as following ether inhalation. They usually occur in persons who are suffering from some pathological conditions of their kidneys.

2. **Circulatory — Ether-collapse.** — After a very prolonged administration of ether, when large quantities are used, the patient may become dusky, the respirations shallow, the extremities cold, and the circulation poor. Especially is this liable to occur when the operation has been severe. Shock so arising, whether due to overdosage of the anæsthetic, or to this coupled with surgical shock, is best treated by the feet-raised position, heat applied over the body and a sinapism on the precordium.

Syncope or **faintness** following ether inhalation except as a

* *Trans. of Med. Soc.*, vol. xxxiv., 1911.

concomitant of "collapse," or unless arising from persistent vomiting (*vide infra*), is very unusual and in my experience only occurs in the case of persons predisposed to syncope.

3. **Hæmorrhage** into the brain or medulla has been noted as a result of rupture of an artery after ether inhalation. It is not easy in such cases to eliminate coincidence, but cerebral hæmorrhage has certainly been found post mortem in cases of death under ether. On two occasions I have known this accident to happen to patients for whom I was to have given ether, but who died from the hæmorrhage a day or two before the operation was to take place, and so before any anæsthetic had been given. Had the hæmorrhage occurred during the etherisation the natural inference would have been drawn that it was the result of the ether inhalation.

Bearing in mind this danger and that of embolism, it is certainly wise to avoid ether for subjects whose blood-pressure is unduly high and who suffer from arterio-sclerosis or from blocked veins.

4. **Renal complications.**—As had been pointed out above, the most conflicting evidence has been advanced about the effects of ether upon the renal mucous membrane. Clinically many observers have noted more or less severe nephritis, hæmaturia, diminution, and even suppression of urine following the use of ether. Albuminuria not infrequently follows its use, and when existent before the ether is taken it is commonly increased after the administration. My own experience is that when ether is carefully given renal complications are very exceptional, even albuminuria is unusual and suppression of urine most rare. I have used ether without untoward results following the inhalation when it was known that kidney disease existed. Still many careful observers have found such complications, and it would appear better to avoid the risk if there is no very cogent reason for the use of ether in the case.

5. **Gastro-intestinal tract.**

Nausea and **vomiting** in some cases may prove troublesome and very intractable. They usually occur in persons whose general health has been impaired before taking the anæsthetic. All food and stimulants must be withheld for three or four hours after ether, and the patient be encouraged to take teaspoonfuls of *hot water*; tepid water provokes more vomiting, hot water checks it. The use of metal spoons in so administering the water should be avoided, so that the lips and tongue may not be blistered. I

have found that when sipping hot water fails, a copious draught
of it will often succeed. In some cases iced soda-water in sips is
useful, while iced black coffee with a dose of bromide of sodium or
of ammonia is often efficacious (gr. x. to a small cupful). Ab-
solute quiet must be observed, the patient being placed in an
airy room, with windows open, if the weather permit it. He
should be well covered with blankets or rugs. In lesser degrees
of sickness, sucking pieces of ice is useful, but the loading of
the stomach with ice-cold water is a measure often followed by
great sickness and discomfort. Covering the face with a thin
handkerchief on which is dropped toilet vinegar will frequently
check the tendency to sickness. Mackenrodt suggests cider
vinegar ; or essence of orange may be used (Gwathmey).

For persons known to be subject to severe ether sickness a
dose of chlor.-butyl (gr. xv.) given one and a half hours before
the administration of ether is said to be useful. I have met
with some success with this plan. Aspirin (gr. xv.) given by the
bowel in saline is often successful, and when the subject is in a
feeble state an ounce of glucose may be beneficially added to the
saline in which the aspirin is mixed.

Should vomiting continue and there is accompanying collapse,
iced dry champagne may be given in teaspoonful doses every
quarter of an hour until improvement occurs. A mustard-leaf
over the pit of the stomach will often prove beneficial. In per-
sistent vomiting Kussmaul's method of lavage is recommended
by Rhoades.* He introduces an Ewald's tube and syphons in
and out warm boric acid lotion (gr. v. to ℥i.). When vomiting
is feared rectal feeding for forty-eight hours should be adopted,
and glucose be freely given, as it maintains the strength and helps
to break the vicious circle engendered by the exhaustion follow-
ing the vomiting.

Some persons suffer from great nausea without much sickness.
Small doses of tincture of nux vomica will do good in these cases ;
one minim in a teaspoonful of water, by preference hot, may be
taken every ten minutes for an hour. This will generally check
the nausea, and failing it, Dr. Ringer's suggestion of drop doses
of vinum ipecacuanhæ may be tried. Dilute hydrocyanic acid
in minim doses is also useful. Hæmatemesis has been recorded
as having followed the use of ether. I have never met with a
case of this, but I have seen several cases which appear to be of

* *Therapeutic Gazette*, Oct. 1897.

somewhat the same nature. After severe operations upon the stomach or intestines and occasionally after those upon the uterus, especially hysterectomies, the patient will vomit dark brown or red material looking like digested beeftea. It appears to be altered blood, but its source is doubtful. As a rule it disappears after general treatment and rectal feeding, but occasionally forms a symptom occurring in cases which terminate fatally. It is hard to resist suggesting some causal relation between this symptom and grave shock, even though the nexus is at present inexplicable. Stercoraceous vomiting occurring during and after operations for the relief of intestinal obstruction is considered later on.

Hiccough, which is sometimes very severe after ether, may be cured by mustard ($\mathfrak{Z}$j, infused and added to $\mathfrak{Z}$iv. of boiling water) taken in sips. Less unpleasant remedies are oil of cajuput, chloral hydrate, and morphine (administered hypodermically). A small cup of strong green tea, taken hot and without sugar or milk, will often check hiccough. The thirst, sometimes a troublesome result of ether inhalation, will frequently disappear if rectal injections of hot water or saline are given.

Diarrhœa and passage of blood per anum after rectal etherisation should be treated by emollient injections containing opium, while the general strength of the patient should be attended to, and his collapse treated upon general principles.

Coma.—Cases of diabetic coma may follow ether inhalation in the case of glycosuric patients, and the consensus of opinion at present points to the advisability of adopting either spinal anæsthesia or local analgesia for such patients rather than the use of general anæsthetics. The treatment of the condition must be conducted on general lines, and is, unhappily, seldom of much avail. Pronounced albuminuric coma deepening and ending fatally has also been recorded after etherisation. **Jaundice** persistent for weeks may occur, but is a rare complication ; nor is it at all clear what relation the anæsthetic has to the condition unless ether has been given in too large a quantity. The treatment is conducted along usual lines.

Deaths during Ether Narcosis.

In the *Lancet* Report * seventy-nine deaths are quoted and particulars of the cases are given. The causes assigned may be summarised thus:—

* *Op. cit.*, p. 165.

Imperfect anæsthesia producing shock.—Asphyxia from blood, vomit, or regurgitated intestinal contents entering the trachea ; respiratory spasm ; bronchorrhœa.

Cerebral apoplexy in a case of senile degeneration of the arteries, embolism, " heart failure," " paralysis of the heart," heart failure during stage of excitement with struggling.

Pulmonary conditions.—Bronchitis in an emphysematous patient, congestion of the lungs, pleurisy with effusion, pneumonia, pulmonary œdema, diphtheritic laryngitis, and emphysema.

Renal conditions.—Uræmia, " from pre-existing kidney disease."

The autopsy in these cases showed the most common lesions to have been chronic disease of the lungs (mainly emphysema), of the heart, and of the kidneys. In several cases death resulted from mechanical asphyxia ; one from pressure of a goitre, one in which undigested food became wedged behind the larynx, and several of fæcal material passing into the lungs of patients suffering from intestinal obstruction. In another case, an ether adapted only for local anæsthesia was inhaled with a fatal result. As would be expected, many of the deaths attributed to ether were those of patients who were *in extremis* at the time of the operation, and for whom ether had been selected in order to supply some stimulant to counteract the profoundly collapsed state. There is very little doubt that none of the cases reported were deaths from overdosing with ether. There were several cases in which anæsthesia was clearly never obtained and death from shock took place ; while in most of the cases the choice of the anæsthetic appears to have been a faulty one. There can be no doubt in the mind of any experienced anæsthetist that in many cases of pre-existing respiratory embarrassment, in chronic lung disease, in advanced renal disease, and when the arteries are old and rigid, the use of ether may easily produce fatal results such as are mentioned in the Report above cited. In the Report of the British Medical Association * four deaths are recorded as definitely associated with the anæsthetic and two more or less certainly classified. Death was due in two cases to aspiration of stercoraceous material into the lungs. In the third case syncope occurred in a feeble anæmic woman lying on her left side. The heart failure occurred as a kidney was being manipulated, and was coincident with vomiting. The fourth

* *Op. cit.*, pp. 61 and 64.

case was that of a man who was in an extremely grave condition and died before the commencement of the operation. Cerebral hæmorrhage and uræmia occurred respectively in the remaining two cases, but several days subsequently to the administration of the ether. Most of the deaths recorded by Gultz, in his statistics of deaths under ether in Germany, were attributed to pneumonia, but, as has been pointed out, many of the fatalities were, in fact, the result of auto-infection, and others were due to the injudicious methods adopted, by which excessive quantities of ether vapour flooded the lungs for prolonged periods.

Cases of death occurring during ether anæsthesia have been reported which are stated to have been caused through " status lymphaticus," but as such fatalities appear common to every form of anæsthetic no special mention need be made of them in this chapter. The condition itself is fully dealt with in the section devoted to the dangers and complications of anæsthesia (*vide infra*). Deaths and dangers incident to special methods of giving ether are referred to in the sections dealing with such methods. The dangers of ether in many cases are enhanced when it is given by an inappropriate method, but minimised if ether is used by a method suited to the exigencies of the patient.

CHAPTER V.

CHLOROFORM.

Chemical and physical properties.— Chloroform, trichloro-methane ($CHCl_3$), is a colourless transparent liquid with a specific gravity of 1·527. When quite pure it is unstable, and a small quantity of alcohol is always added as a preservative; 0·5 per cent. or 1 per cent. of absolute alcohol is usually added, lowering the specific gravity to about 1·490 or 1·495. It is soluble in water (1 in 200) and freely miscible with absolute alcohol, ether, benzine and oils. It has an agreeable ethereal odour and sweet, burning taste. Its vapour is not combustible, but if mixed with alcohol and ignited it burns with a smoky flame having a greenish edge. It is very volatile, but although mixing freely with air, pure chloroform vapour can only exist at a temperature of 140° to 143·6° F. (60° to 62° C.). Thorpe gives the boiling-point as 61·2° C. and its density at 0° C. as 1·5266 compared with water at the same temperature (Allen). When exposed for some time to light, chloroform splits up into chlorine and hydrochloric acid. Chloroform vapour diffused in a hot room when illuminating gas or an open fire is burning decomposes in the presence of moisture, and suffocating fumes are liberated. I have noticed that this decomposition occurs when a powerful electric lamp is held over the chloroform inhaler. These fumes are composed of carbon oxychloride, $COCl_2$ (phosgene gas) and hydrochloric acid; $CHCl_3 = COCl_2 + HCl$. To test-paper chloroform should be absolutely neutral.

TRADE VARIETIES.

Three varieties of chloroform are known in commerce, pre-pared respectively from duty-paid rectified spirit, industrial methylated spirit, and acetone. When carefully purified the

three varieties cannot be distinguished by chemical tests, although the varieties prepared from rectified and methylated spirit are said to contain traces of ethyl chloride (Wade and Finnemore).* Chloroform prepared from duty-paid rectified spirit costs considerably more than chloroform prepared from acetone or from industrial spirit. During the war the relative cost has varied, at present the acetone and methylated kinds cost about the same, and that prepared from rectified spirit costs double.

Other varieties of chloroform in much smaller demand are chloroform prepared from chloral hydrate, which is naturally very expensive, and Pictet's chloroform, obtained by exposing pure chloroform to a temperature between —80° C. and —82° C. and removing the crystals of frozen chloroform from the surrounding fluid.

Commercial chloroform is usually fairly pure ; the following are the principal tests :—

Residue.—Ten c.c. evaporated in a shallow glass vessel on a water-bath should leave no visible residue.

" Smell " Test.—When 10 c.c. are poured upon a filter-paper and allowed to evaporate no foreign odour should be perceptible during the evaporation and when all the chloroform has volatilised, the filter-paper should be quite odourless.

Free Acid, Chlorine, and Chlorides.—When 5 c.c. of chloroform are shaken for five minutes with 10 c.c. of distilled water and the upper aqueous layer is afterwards decanted from the undissolved chloroform, the watery layer should not redden blue litmus paper (absence of acid), it should not afford a blue colour when mixed with a few drops of dilute solution of cadmium iodide and mucilage of starch (absence of free chlorine), and another portion of the aqueous layer should yield not more than a very slight opalescence on the addition of silver nitrate solution (absence of chlorides).

Chloroform should be kept in a cool, dark place in glass-stoppered bottles.

Dr. F. W. Tunnicliffe † has made some careful experiments

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* *Journal of Chemical Society*, July 1904, p. 938. See also *Trans. Soc. Anæsth.*, vol. vii. p. 89, where it is stated that the addition of 0·25 per cent. of ethyl chloride to acetone chloroform renders it physiologically identical with alcohol chloroform.

† *Journal of the Royal Army Medical Corps*, vol. ii. No. 4, p. 459.

with chloroform and chloroform residues to test whether their toxicity becomes increased as a result of keeping, transport, etc. The specimens examined were taken out to South Africa and subsequently sent to England, where the examination took place. The conclusion arrived at was that when the chloroform is initially pure, except for the added alcohol, it remains free from pharmacological deterioration under the ordinary conditions of military transport. This, of course, assumes that the bottles which contain the chloroform are kept closely stoppered and protected from a strong light.

According to Sir William Ramsay, when chloroform is kept over slaked lime and decanted off before use it remains pure. On the other hand, Mr. David Brown * asserts that contact with lime causes a rapid decomposition of chloroform. The addition of 1 per cent. of alcohol will, M. J. Regnauld believes, keep chloroform pure even if left exposed to light.

The General Physiological Action of Chloroform on the Body.

Upon the skin and abraded surfaces, chloroform benumbs and acts as a strong irritant, and, if evaporation of the condensed vapour be prevented, causes vesication. Severe injury has resulted from dropping chloroform on the face or allowing the vapour or liquid to come into contact with the conjunctiva. Vomit containing condensed chloroform will cause similar results.

When introduced into the body by inhalation, by being drunk, or by intravenous injection, the effects are the same, varying perhaps in degree, but agreeing as to results, allowance being made for the method adopted for its introduction.

Harley pointed out that chloroform destroys the red corpuscles of blood. This may possibly, he thinks, explain the occasional supervention of jaundice after chloroform narcosis. I examined the blood in a large number of cases before and after the patients had taken chloroform, and found both a lessening of the number of red corpuscles and an actual increase in the number of white corpuscles with some lowering of the hæmo-

* *Pharmaceutical Journal*, Dec. 14, 1898.

globin index. These findings are corroborated by the more recent work of Dr. Theodore Casto.* However, many other factors, such as restriction of diet and loss of blood, probably play some part in bringing about the result. It has been shown by Moore and Roaf † that hæmoglobin and serum protein possess the property of retaining chloroform in the blood, while Vernon Harcourt and Victor Horsley ‡ have demonstrated that this is also true of the corpuscles. So long as they maintain their morphological integrity, they possess this property and are thus the active agents in conveying chloroform to the tissues of the body. It seems probable from the experiments of Moore and Roaf that chloroform is not absorbed according to the Dalton-Henry Law, but, like oxygen and carbon dioxide, becomes associated with or forms what these observers term an " aggregation " with the proteid constituents. It thus causes a gradual lessening of all biochemical activities, the extent of which is determined by the solution tension of the chloroform in the blood with which the tissues are brought into immediate contact. When this tension exceeds a definite limit not only is the power of function stayed, but the life of the protoplasm is destroyed. This catastrophe is hastened when the oxygen content of the blood is diminished, a fact which explains the signal danger of chloroform narcosis when associated with asphyxia. Buckmaster and Gardner found that during narcosis arterial blood becomes progressively richer in reduced hæmoglobin, and hence it is probable that chloroform interferes with the transport of oxygen by the erythrocytes. Buckmaster has proved also that the blood becomes more concentrated, and so its bulk is lessened and its specific gravity increased by absorption of chloroform.

Professor Haldane § has indicated the effects of anoxæmia upon the circulation and respiration, pointing out that the defective supply of oxyhæmoglobin such as may occur under chloroform is one of the factors in bringing about the vicious circle which culminates in anoxæmia.

Upon the blood corpuscles out of the body chloroform certainly acts as a solvent. It is a protoplasm poison rapidly destroying

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* *American Yearbook of Anæsthesia and Analgesia*, 1915, p. 31.
† *Proc. Roy. Soc.*, vol. lxxiii. p. 382.
‡ *Brit. Med. Jour.*, July 23, 1904.
§ *Ibid.*, July 19, 1919.

the contractility of muscle and the irritability of nerve tissues.*

Prolonged inhalation of chloroform repeated day after day for a considerable time is said to lead to fatty degeneration of the tissues, and it is further asserted that like changes occur in a less marked degree even when but little of the narcotic is taken. Changes in the liver resembling those seen in acute yellow atrophy of that viscus, also swelling and subsequent destruction of the epithelium lining the tubules in the kidneys, have been recorded. How far such destructive changes are due to absorption of excessive quantities of the anæsthetic there is as yet no evidence to prove, although it seems probable that many of those who have experimented have failed to differentiate between chloroform employed as an anæsthetic in definite low percentage vapour, and the toxæmia incident to chloroform introduced into the organism in high percentages. The author has considered this subject in a paper contributed to the Medical Society of London.†

The various parts of the nervous system appear to become affected in the same order as obtains in the case of ether, the **cerebral centres** are influenced before the **sensory** fibres of the **cord,** these before the **motor** fibres, while last of all the **medulla oblongata,** containing the centres which control respiration and circulation, becomes paralysed. The superficial and deep reflexes disappear as the various degrees of narcosis are reached, the nasal and rectal being among the last to go. The reflexes concerned with circulation and respiration—vagal reflexes— are only lost when the medullary centres become paralysed. The ocular reflexes persist up to the fourth degree, except the conjunctival, which disappears as the patient enters the stage

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* Hans Meyer's and Overton's views on this subject are interesting. They have advanced the theory that chloroform and some other anæsthetics are rapidly absorbed by the lipoids, and since these bodies are found largely in the cell tissues of the nervous system a quasi-election by certain anæsthetics of nervous tissue is found. Bert and recently Collingwood have shown that prolonged inhalation of chloroform vapour, even in percentages incapable of inducing anæsthesia, will kill dogs and other animals by its effect upon metabolism. The temperature under such circumstances gradually falls, and death follows at periods determined by the strength of the vapour inhaled. Intermittent daily inhalation eventually kills by bringing about degenerative changes in the viscera.

† *Proc. Med. Soc.,* 1912, vol. xxv. p. 280.

of true anæsthesia. Until the blood has received enough chloroform to produce profound narcosis—*i.e.* has been in the third degree for some while—and the corneal reflex has become dulled, strong sensory stimuli will in many patients appear to cause them to respond as if they were only lightly narcotised. This is probably effected by increased pulmonary ventilation induced reflexly.

As stated above, chloroform has been believed to possess a selective action upon the tissues of the nervous system, analysis of the tissues of persons who have been killed by chloroform showing that the brain and cord contain proportionately more of it than other tissues (Lallemand, Perrin, and Duroy). Julius Pohl has also found that the brain of narcotised subjects contains more chloroform than the blood taken from the afferent blood-vessels. What is the nature of the action upon the nerve centres we are unable to say, but evidence points to the probability that it is exerted upon the tissues themselves. Hamilton Wright[*] has shown that the **neurons** are profoundly affected both by chloroform and by ether, and the effect is proportionate to the duration of the inhalation. Marked, although evanescent, microscopic changes occur with rarefaction of the cell-substance ; these it is suggested may modify nervous function. The effects of anæsthetics upon isolated **nerve** have been carefully worked out by Waller. This observer has shown that, in the case of chloroform, the nerve tissue readily loses its electro-excitability, seven times more easily than in the case of ether, and is liable to be so permanently damaged as to lose it entirely.

It has been proved by Sherrington and Sowton, [†] and by others, that chloroform exercises a direct influence upon all **muscular tissues.** The **muscular fibres** of the heart are very sensitive to chloroform and rapidly lose their resiliency. This probably explains the **acute dilatation** of that organ described by Professor McWilliam and corroborated by Professor Leonard Hill. This action is proportionate to the strength of the chloroform vapour. The voluntary muscles require a much more concentrated and the unstriped involuntary muscles a still higher concentrated chloroform solution or vapour to bring about paresis. Thus uterine contractions are not affected to any

[*] *Jour. Phys.*, vol. xxvi. pp. 39 and 362.
[†] *Brit. Med. Jour.*, July 22, 1906.

appreciable extent unless the patient has been given dangerously large quantities of chloroform.

Chloroform, although possibly in part split up (Zeller), certainly remains mostly unchanged in the body, and is eliminated in the urine, the breath, and the milk.

EFFECTS PRODUCED BY THE INHALATION OF CHLOROFORM VAPOUR.

These vary considerably, according as weak or strong vapours are inspired. When a 2 per cent. vapour is inhaled the ordinary phenomena of anæsthesia occur, while stronger vapours are liable to cause progressive paralysis of respiration and circulation and finally death. Dealing firstly with the physiological effects of dilute vapours, it is convenient to divide the period of narcosis into five degrees.* Of these the third represents **anæsthesia,** and the last two a profound state of narcosis in which respiration and circulation are failing or have failed.

In the first degree—from commencement of inhalation to the impairment of consciousness—fulness in the head, singing, buzzing in the ears, palpitation of the heart, are sometimes felt; there is also some diminution of common sensation. The respiration is hurried, especially when the patient is nervous. The

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* Snow plotted the period of narcosis between initial inhalation of chloroform and death from its extended effect into five empirical degrees. He pointed out that anæsthesia occurred in the third degree, and that any nomenclature which allowed the term anæsthesia to be qualified by such adjectives as complete, imperfect, and so on, introduced an undesirable ambiguity. If a patient is described as in the second degree of narcosis, every reader knows the precise physiological conditions present, whereas if he is said to be in a state of imperfect anæsthesia, no one except the narrator has any clear idea of what depth of narcosis was present except that it was below the third degree, since the patient was not anæsthetic. Similarly the "stage of excitement" equally well describes the second degree of narcosis and the condition of the patient as he is regaining consciousness and after he has passed through the third and even the fourth degrees of narcosis, so that its use, although condoned by custom, must be recognised as being not only unscientific but misleading. Of course Snow's degrees must merge one with another, but the clinical phenomena which characterise them are quite definite, and so they can be differentiated one from another, and mark epochs in the patient's progress. French physiologists, however, restrict themselves to three degrees, thus introducing fresh complications.

circulation is accelerated and the pulse may be at first fuller, but soon grows weaker. The pupils are sensitive to light and are moderately dilated, and the ocular globes move. The patient will look at you and follow with his eyes. The senses are confused, but the patient often will obey when spoken to loudly.

In the second degree the mental powers are impaired although not suspended. The patient at first remains passive as if sleeping, or occasionally makes a semi-voluntary movement. Sometimes laughing, singing, talking, are indulged in. Snow believed that dreaming occurs at this time and then only. It is probable, however, that dreaming also occurs in the subliminal stage of recovery, and that such dreams are at times remembered, whereas the earlier ones are seldom recoverable.* When more deeply narcotised the patient becomes restless, he attempts to remove the face-piece or inhaler, for he is conscious of being inconvenienced by the vapour, but not of the necessity for remaining passive. Common sensation is much blunted, so that patients submit without expostulation to painful manipulation. This degree of narcosis is commonly relied upon for assuaging the pangs of parturition and for the after-stages of prolonged operations. As a rule, struggles or expressions of pain which show themselves at this time are not remembered subsequently. The respiration and circulation are both quickened, the former being rendered more shallow and at times interfered with by contractions of the skeletal muscles and of the diaphragm. Spasm of these muscles may occur, accentuating this cause of respiratory disturbance. The pulse, accelerated at first, towards the close of this degree drops to or below the normal rhythm and is weakened in force, and blood-pressure falls. The ocular globes remain movable, the light reflex persists, and the pupils are dilated. Salivation and a desire to expectorate are commonly present. It is never wise to operate until the third degree of narcosis has been attained, since, as has often been pointed out, under light narcosis there is a peculiar danger of heart arrest, so that complete anæsthesia should always be obtained before even

* The whole subject of dreaming under or during the state of narcosis is as interesting as it is illusive. It may be hazarded that increased cerebral vascularity makes for hallucination and dreaming. A fact for which several patients of mine vouch, is that the dream may be repeated or continued—the *mise en scène* being identical on occasions of being anæsthetised even although the taking of the anæsthetic occurs at intervals widely separated.

manipulation is attempted. Dr. Levy's explanation of this danger is referred to below.

In the third degree all voluntary movements are lost and complete anæsthesia is present. As the patient is passing from the second to the third degree, the conjunctival vessels become full ; the muscles are rigid, and struggles, even epileptiform convulsions, may supervene. When the narcosis becomes deeper the muscles relax, phonation and mouthing cease. Although really insensitive to pain, the patient may in the early part of this degree wrinkle his forehead, flinch, or even cry out. Later on, reflex acts are abolished, the conjunctival and nasal reflexes receding late. The patella jerk persists for some time, while under deep anæsthesia the ankle-joint phenomenon may appear.

The rectal reflex influence upon the respiration will usually persist throughout this degree of anæsthesia. The respiration and circulation settle down to the normal, or even grow distinctly weaker, and some pallor may be seen and blood-pressure be markedly lowered. The buccal muscles ceasing to act, the cheeks are blown out during expiration, the chin drops, through the weight of the tongue, and interference with breathing may result from the falling back of the tongue towards the laryngeal aperture. The ocular globes now become fixed, and although the light reaction persists the conjunctival reflex is completely lost. The pupil contracts and remains smaller than normal. The lower lid no longer travels upwards to protect the globe as it does in the lighter degrees of narcosis when the upper lid is lifted.* In rare cases the skin shows a slight rash like that seen in ether narcosis, but this rapidly disappears, leaving the skin cold and pale.

The fourth degree.—At this period the patient is profoundly unconscious and passing into the danger zone ; the centres controlling respiration and circulation in the medulla oblongata are unduly narcotised and respiration and circulation enfeebled. Such deep narcosis is seldom needed, save for the reduction of old-standing dislocations, in deep dissections, in some abdominal operations, especially those above the umbilicus and in the case of alcoholics. As a rule all these cases can be successfully dealt with provided the patients are allowed to remain undisturbed in the third degree of narcosis for a

* This is a valuable sign which I have observed, and is no doubt of the protective reflex type.

quarter or half an hour. In this way a sufficiently profound degree of narcosis is obtained. It is a good rule in these circumstances to defer the commencement of the operation until the breathing has settled down into an even rhythm, full and regular. This degree is marked by corpse-like flaccidity of the muscles, pallid or bluish skin, deep stertorous breathing gradually growing difficult, irregular, shallow, and unduly diaphragmatic, while the pulse is quick, compressible, and feeble, becoming almost imperceptible. The blood-pressure again sinks until the heart is unable to carry on the circulation. The ocular globes are fixed, the pupils are widely dilated and no longer react to light. This degree corresponds to increasing paresis of the centres of respiration and circulation.

The fifth degree is the interval which, following the fourth degree of narcosis, intervenes between the respiratory embarrassment and total cessation of breathing. Even after dyspnœa has been succeeded by cessation of respiration the heart may beat feebly for a brief space, the circulation growing more weak and the heart eventually stopping, although if examined it will be seen to evince fibrillary contractions. In this degree the centres in the medulla oblongata are irretrievably damaged, and no longer able to conduct or control the essential processes of life. Gradually failing respiration culminating in its complete cessation, followed by complete failure of the circulation with paralytic dilatation of the heart, wide dilatation of the pupils, extrusion of fæces and urine, mark this final and fatal degree of narcosis.

The phenomena described as occurring in the degrees of narcosis vary somewhat in different persons. In the alcoholic, for example, the excitement is very marked and prolonged. These persons may remain restless, their muscles being rigid and movements occurring even when they appear to be completely under the influence of the anæsthetic. It has been noticed that soldiers, especially those who have been subjected to severe war stress, require unusually large quantities of anæsthetics before they become profoundly anæsthetised. Neurotic people also are prone to move and appear restless, their respiration and circulation may be, and commonly are, adversely affected by reflex influences even when the usual signs of anæsthesia are present.

It may be convenient now to consider more in detail the

phenomena which appear as the patient passes under the influence
of chloroform. It must be clearly understood that the pheno-
mena are revealed by a continuous process in which there is
no break ; thus unconsciousness is the effect of chloroform upon
the higher centres in the brain ; but as these come under the
influence of the drug, so do the heart and its nerve controls, and
so do the centres in the medulla oblongata which functionise
the systems of circulation and respiration. It is true that a
patient may and does remain unconscious, his heart-beat and
vaso-motor functions and his respiration being maintained
in safety, but unless the action of the chloroform is kept within
certain limits, these functions are gradually interfered with and
danger or death results.

The effects on the circulation of the blood.—The arterial pressure
is said to undergo an initial rise, but the rise, if it occurs at all,
which many observers doubt, is commonly slight, and is due, if
we accept the experimental work of Gaskell and Shore, to an
initial stimulation of the vaso-motor centres. This is followed
at once by a gradual fall of blood-pressure due to progressive
weakening of the heart muscle. Schäfer and Shirley assert
that a dilatation of the renal vessels occurs under chloroform,
and this assists in bringing about the fall in blood-pressure.

Embley and Martin, relying upon their investigations upon
the circulation of the kidneys and small intestines, have come
to the conclusion that although vaso-constriction results from
high percentages of chloroform, yet if the percentages are kept
at or below the level which is possible when the vapour is inhaled,
vaso-dilatation invariably results, and as a consequence deple-
tion of the arterial system and filling of the venous system
occur.

The pulse of the patient is quickened as he commences to
inhale and slightly increased in force, but it rapidly grows less
full and may become markedly feeble. The fall in blood-pressure
is admitted by all competent authorities, but the interpretation
of its cause is matter of dispute. McWilliam has shown that as
soon as chloroform enters the circulation, and its absorption by
the pulmonary vessels is extremely rapid, it is conveyed through
the coronary vessels to the heart muscle. The result is evidenced
by weakening action as the heart gradually loses its contractility
and finally passes into paralytic dilatation. The research of
Sherrington and Sowton has made it clear that even very small

quantities of chloroform act at once upon the heart muscle, but, provided that the amount of the anæsthetic does not exceed a certain limit, the muscle accommodates itself to the chloroform, and its force of beat, although lessened, is not unduly diminished. When, however, the percentage dose of chloroform is increased, and the limit is a narrow one, the heart muscle becomes paralysed and is irrecoverable. This confirms observations which I made some years ago working with the detached heart of the frog. The weakening of the cardiac contractions undoubtedly leads to a fall in the blood-pressure. As a result the nerve centres, like the heart muscle itself, become deprived of their proper blood-supply and cease to maintain the regulating mechanism of the blood circulation. Leonard Hill, in the course of his valuable work on this subject, has shown that when the central nervous system is deprived of its due supply of blood it is more readily affected by chloroform, as indeed it is by all narcotic poisons. A percentage which will not prejudice the nerve centres of a person whose blood-pressure is normal will prove fatal when the blood-pressure has undergone declension. And not only does this occur, but as a result the tonus of the whole arterial system becomes damaged or destroyed, and the blood drains from the arteries into the veins. The force of gravity which in the physiological state assists the circulation now causes the blood to accumulate in the large veins of the abdomen (" the abdominal pool " of Hill) and the circulation comes to a standstill. The truth of these statements was called in question by the work of the Second Hyderabad Commission, but it must now be admitted that all physiologists are agreed upon the matter, and claim that the tracings published by the Hyderabad Commission themselves demonstrate the gradual weakening of the heart under the influence of chloroform. The great merit of the work done by the Hyderabad Commission, and its value cannot be over-estimated, undoubtedly is the abundant proof which the experiments afford of the dangers of obstructed respiration. Although primary heart failure probably does occur in any degree of chloroform narcosis—but this the Commission denies—yet one of the commonest causes of death under chloroform is interference with respiration through overdosage, and secondly, failure of circulation. Leonard Hill, however, has indicated that although this reasoning is apparently correct, yet, as a matter of fact, the sequence of events is a vicious circle. The patient in-

hales an overdose of chloroform, an overdose usually due to too high a concentration of the vapour, so that the blood-pressure falls in spite of a possible initial rise due to asphyxia, and the respiratory centre ceases to receive its proper supply of blood. Then comes respiratory embarrassment and ultimately fatal interference with circulation.

The mechanism by which this " primary heart failure " occurs has been described by Leonard Hill and may be given in his words :—" Concentrated vapour of chloroform is presented to the respiratory orifice, the nerve endings of the sensory fibres of the vagus in the respiratory tract are powerfully excited. The animal struggles, the glottis is closed, and by the violent contraction of muscles the intrathoracic pressure is raised. . . . The effect of raising the intrathoracic pressure is to diminish the output from the right heart, to congest the venous system and lower the arterial tension ; the lungs are also compressed and to a great extent emptied of blood. Blood-supply to the coronary arteries is diminished ; this is due to the fall of arterial tension. The oxygen in the blood is decreased owing to the prolonged holding of the breath. By these means the nutrition of the heart is impaired. Finally, owing to the excitation of the respiratory centres caused by the asphyxial blood, the animal is forced to take two or three deep inspirations. The lungs are immediately surcharged with chloroform vapour, and the blood reaches the coronary arteries carrying a dose of chloroform sufficient to throw the heart into paralytic dilatation." Syncope arising thus early in the inhalation appears to explain a large proportion of the fatalities which have occurred under chloroform. It is usually reported that " the patient struggled, became suddenly pale, the heart stopping, and after giving one or two gasps, died without showing any response to artificial respiration." Sherrington has shown that, provided the concentration has not been too great, recovery will take place, since blood-pressure has not fallen too much and the heart muscle has not undergone the " paralytic dilatation " of McWilliam. Dr. A. G. Levy,* as the result of experimental work, has advanced the

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* See *Heart*, vol. iii. p. 99 (with Dr. T. Lewis) ; vol. iv. p. 319; vol. v. p. 299; *Jour. of Physiology*, vol. xlii.; *Proc. Physiol. Soc.*, Jan. 1911 ; also *Jour. of Physiology*, 1914, p. 54 ; *Brit. Med. Jour.*, 1912, vol. ii. p. 627 ; *Proc. Roy. Med. Soc.*, vol. vii. p. 37 ; 1909, vol. ii. p. 205, Section of Anæsthetics ; also vol. iv. p. 205, Section of Pathology.

view that chloroform is primarily a heart irritant, and tends under certain circumstances to induce ventricular fibrillation, a condition which may prove fatal. This, he contends, happens only under light anæsthesia (narcosis), and may occur during the induction or recovery from chloroform anæsthesia. He found that minute doses of adrenalin and drugs of similar action which are heart stimulants, when given in association with chloroform, at once caused fibrillation. Cardiac irregularity was then induced, although it does not ever arise when a full chloroform effect is present. In practical anæsthesia, when adrenalin is not given, deaths from this cause may, however, arise, and Levy contends that they are always due to under, rather than to over-chloroformisation. Further, we now know, from the work of Cannon and de la Paz, which has been confirmed by Elliott, that fear, anger, and indeed emotional states generally, cause an abnormal secretion of adrenalin in the body, so in this case the individual may be said to manufacture his own death poison. Levy summarises his results as follows:—Deaths under light chloroformisation may be observed under any of the following and allied conditions : (A) During induction : (1) when there is struggling and excitement ; (2) on intermitting the inhalation ; (3) abrupt reapplication of chloroform after intermitting it or a sudden increase of strength of the vapour ; (4) any combination of the above. (B) During the operation. Strong sensory stimuli when the patient is lightly under the anæsthetic. (C) After the operation. During the period of recovery when the chloroform is no longer inhaled, especially after a short operation. In this case, presumably, there must be some exciting cause, since during recovery from chloroform anæsthesia there must be a period when the patient passes through a zone of light narcosis. The point appears to be that when the patient has been lightly anæsthetised by chloroform, especially when this is done by a method permitting an irregular or intermittent supply of the anæsthetic, the heart muscle passes into an irritable state, and this engenders fibrillation ; the most dangerous periods being those of induction and recovery, in both of which the strength of the chloroform vapour is apt to be marked by more or less sudden variation. Children, Levy considers, are less liable to this danger than are adults. Although this theory may account for some of the recorded cases of sudden collapse during the induction period, it can hardly, I think, be

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accepted as explaining the causation of most of the fatalities occurring under chloroform. It enforces the teaching which has been current for many years that undue prolongation of the period of induction due to irregular administration of excessively feeble vapour is dangerous, and that, provided the **breathing is unobstructed,** the strength of chloroform given should be steadily increased and the supply made continuous.

A further consideration with regard to primary syncope under chloroform is the danger of heart failure due to fear.

In the days when anæsthetics were not commonly used, death before the operation was not uncommon and was attributed to fear. A similar experience is at the present time to be met with during the use of local analgesia. The patients in many cases, although suffering no pain, vomit and faint from the emotion of seeing and hearing the steps of the operations upon their bodies. Now, with respect to fear-syncope under chloroform, it might be supposed that the chloroform inhalation was merely a coincidence with the syncope, if it were not for the fact that such cases of fear-syncope are extremely rare, if they ever occur, under ether. Probably, the depressant action of the chloroform on the one hand, leading to weakening of the heart-beat with concomitant fall of blood-pressure, and the stimulating effect of ether on the other, with the increased cardiac contraction, make all the difference in the ultimate issue of the case.

In the later degrees of chloroform narcosis syncope may arise from another cause. The diminution of arterial tension incidental to the continuous chloroform action causes ischæmia of the medulla oblongata, and this leads to the progressive weakening of the respiration. However, chloroform still enters the lungs and is conveyed to the circulation. There need be no undue concentration of vapour in the ordinary sense, although the continuous inhalation of the vapour of the particular concentration produces overloading of the blood with chloroform, and slow but progressive fall in arterial tension. As the respiratory centre becomes anæmic it is more readily paralysed by even a small quantity of the narcotic, and ultimately becomes unable to carry on its functions. As the respiration progressively fails, so does the circulation grow feebler and finally ceases. This gradual syncope is, according to Hill, not the result either of respiratory failure or asphyxia. After respiratory failure, if the heart is still able to contract, as a rule the patient can be

restored when artificial respiration is carried out. In the sudden failure of circulation arising from paralytic dilatation of the heart or ventricular fibrillation no resuscitative measures are of much avail, although heart massage (see below) offers some hope. It may again be pointed out that even here *watching the respiration*, if done effectually, would safeguard the patient, especially if, as should always be the case, the degree of pallor of the lips be observed. Whether accumulation of chloroform can take place in the blood, even when a comparatively dilute vapour is being inhaled, is at present open to question, but it seems at least probable that accumulation in a certain sense does occur. Vernon Harcourt's investigations appear to prove that, during prolonged inhalation of chloroform, the expired air at first contains more than half the amount of chloroform inspired ; later, a larger quantity is given off, and when the anæsthetic is given in lower percentage the expired air may contain more than that inspired. These statements are only true when the respiration remains unembarrassed ; impeded breathing must eventually lead to accumulation of chloroform in the tissues. It is certain that the force of expiration gradually fails during prolonged chloroform inhalation, and so, if the expired air does not eliminate sufficient chloroform vapour, a gradually deepening degree of narcosis must occur. This takes place so slowly that only the greatest care enables the administrator during a protracted operation to recognise the over-narcotism. In the emphysematous, expiration being ineffectually performed, even from the first, there is an especial risk of this happening. And again during protracted operations, when bleeding is severe, the lessened quantity of the blood in the body will render a much smaller dose of chloroform sufficient to paralyse the medullary centres. Struggling plays an important part in bringing about syncope under chloroform in the period corresponding to the first two degrees of narcosis. It increases the liability to an augmented intake of chloroform, and by causing fixation of the thorax raises the intrathoracic pressure, and so puts a severe strain upon the heart as well as interfering generally with the mechanism of circulation. Such interference must tell with especial force upon the cerebral circulation. The effect of posture also is one of primary importance upon the determination of syncope. As Hill has shown, when the vaso-motor system is rendered paralytic by chloroform the " stopcock action " of the

capillary system ceases to work, and, as a result, the arteries at once empty themselves of blood. The force of gravity, when the vaso-motor system is intact, assists circulation, otherwise it favours the accumulation of the blood in the veins. In these circumstances, when the person is placed in the feet down posture, the brain and medulla are at once emptied of blood and the medullary centres, being anæmic, cannot energise. Several deaths have occurred of persons who, during a recovery from profound narcosis, have been either lifted or have risen into the sitting position and have at once fainted and died.

Embley, who investigated the causation of sudden death during induction, believes that the vagus nerve mechanism plays an important part in bringing this about. The vagus nerve, when influenced by chloroform, rapidly obtains an increased power of inhibition over the heart. As we have shown, the anæsthetic by causing acute dilatation of the heart directly weakens it, causing a fall of blood-pressure. It is this declension of arterial tension which renders the heart less able to escape from the vagus control, and inhibition partial or complete ensues. With cessation of the heart's action the blood-pressure falls to zero and respiration stops. Embley believes that he has proved this dangerous inhibition is liable to occur in the case of the lower animals whenever the strength of the chloroform vapour in the air inspired rises above 2 per cent. Whether, as has been suggested, the vagal action is exercised reflexly through nerve endings in the nasal, laryngeal, or pulmonary areas is open to some question, although it seems probable. It is certain, however, that the theory of such reflex mechanism is insufficient to cover the whole ground. For when all reflexes are experimentally eliminated, vagal inhibition still occurs, and is then due to the hyperactivity of the vagus-nerve-mechanism being induced by the chloroform in the blood stream. This is a danger of the induction period, for when that is safely surmounted the vagus action ceases to make itself felt, its excitability having become depressed. It is liable, however, to be excited again by increasing the strength of the chloroform vapour, or by asphyxia. The degree of readiness with which this can be done depends upon the duration of the administration and the endurance of the vagi. As is pointed out above, Levy explains deaths occurring early in the induction stage of chloroform narcosis by the supposition that ventricular fibrillation is brought about

by insufficient chloroform having been given, and given by faulty methods.

Respiratory System.—As soon as the initial excitement has passed off, the force of the respiratory movements is lessened. The thoracic excursion is obviously diminished as inhalation proceeds. What are the alterations in the gaseous exchanges during light and deep narcosis we have yet to learn, but that these exchanges become progressively less there is every reason to believe.

To understand the mechanism of chloroform narcosis the following facts should be considered :—

Chloroform vapour enters the blood until an equilibrium is established between the tensions of chloroform in the alveolar air of the lungs and that in the blood itself. So long as the tension in the air is maintained equal to or above that in the blood, no chloroform can leave the latter through the agency of the pulmonary mucous membrane. Snow demonstrated this theoretical assertion by actual experiment, substantiating the truth of the *a priori* statement, and so he arrived at the following law :—" As the proportion of vapour in the air breathed is to the proportion that the air, or the space occupied by it, would contain if saturated at the temperature of the blood, so is the proportion of vapour absorbed into the blood to the proportion the blood would dissolve."

The amount of vapour which can be taken up (held in suspension) by the air of the atmosphere, varies with the elastic tension of the chloroform vapour at different temperatures. Thus at 40° F. a small quantity of chloroform would evaporate into air ; at 130° F. so much would volatilise as to give rise to an almost pure chloroform vapour.

Snow * found one grain of chloroform in one hundred cubic inches of air produces the second degree of narcosis, but never carries chloroformisation further. This corresponds to a proportion of one part, by measure, of chloroform in 16,285 parts blood, or 0·0000614 the proportion by weight. Two grains in each hundred cubic inches of air, or $\frac{1}{28}$ saturation (unity being saturation), produces the fourth degree of narcosis, or 0·0001228 the proportion by weight.

Two grains or more in the hundred cause interference with respiration; three grains in the hundred seem about the ratio which renders respiration impossible. Three grains represent 2·3 cubic inches vapour, and as air at 100° F. can take up 43·3 per cent. of

* " Anæsthetics," p. 33.

its volume, the blood must contain from $\frac{1}{18}$ to $\frac{1}{19}$ of the proportion it is capable of absorbing when the respiratory centres are poisoned.

Snow found further, that calculating the weight of the blood as thirty pounds, twelve minims of chloroform in the circulation produce narcosis of the second degree ; eighteen minims would induce the third degree (surgical anæsthesia) ; twenty-four deep narcosis (fourth degree) ; and thirty-six paralysis of the medullary centres. In practice more is needed because a certain proportion evaporates from the tracheal and bronchial surfaces and is carried out in expiration. If twelve minims be evaporated into a bladder and inhaled to and fro, no more air being allowed than can be blown through the lungs, narcosis of the second degree actually results. Now, taking thirty-six minims as a lethal dose, the following considerations, upon which Snow strongly insisted, explain how easily this quantity may enter the circulation if the administrator be not perpetually upon his guard against overdosage ; 18 minims represent the amount absorbed to produce surgical narcosis ; this amount might be absorbed by the use of 36 minims, the remaining 18 minims being exhaled as above mentioned. These 36 minims at 60° F. make 37·5 cubic inches of vapour, and may exist in combination with 257 cubic inches of air, making it expand to nearly 300 cubic inches. The 300 cubic inches would be inspired in twelve respirations of 25 cubic inches. Now, if a vapour of this strength were continuously inhaled, the residual and complemental air would become saturated, and as about 250 cubic inches represent the air in the lungs, this amount would at 60° F. contain the vapour of 30 minims. Assuming only half this quantity to be absorbed, that is 15 minims, we should then have 18 + 15 or 33 minims in the blood, an amount almost if not quite enough to paralyse the respiratory centre. These points being held in remembrance will explain many cases of chloroform death, ascribed to " idiosyncrasy " or the " fatty heart."*

The lesson which these facts appear to the writer to emphasise

* Snow's estimates are probably too low, as he did not allow for the blood which remains in the tissues, after draining away all that is removable from the vessels. The results arrived at by the Special Chloroform Committee of the British Medical Association, published in 1911, are more accurate. This Committee came to the conclusion that any continuous inhalation of chloroform vapour above 2 per cent. eventually produced interference with due performance of respiration and continuance of adequate blood circulation.

is, that chloroform to be used with safety must be employed in low percentages. If we translate Snow's figures into percentages we find that he and Paul Bert agree in fixing a 2 per cent. as the strength of vapour which produces the third or anæsthetic degree of narcosis. Double this and we reach the quantity which kills. The problem is no doubt a complex one when chloroform is administered to a patient, but there is little, if any, doubt that there exists a very narrow margin of safety when we transcend the 2 per cent., and that unless we are prepared to run a considerable risk we must keep within this percentage.

These considerations, which cannot be studied too carefully, point out the importance both of avoiding an overdose of chloroform, and of maintaining a due elimination of the drug. The Hyderabad Commissions again and again urged the grave dangers which followed when asphyxia (by which is meant impediment to thorough air exchange in the lungs) is permitted to complicate chloroform narcosis. Such interference with due pulmonary ventilation of course means impaired elimination, itself tantamount to accumulation of chloroform in the blood. Broadly speaking, it is true to say that a dose of chloroform which is safe, provided due air exchange is ensured, rapidly grows dangerous when its elimination is interfered with. It is thus evidently a fallacy to urge that if only a small quantity of chloroform is given, the patient is free from danger. The peril lies not in the quantity of chloroform inspired when breathing remains unimpeded, but in the strength of the vapour entering the lungs. In this sense breath-holding and lowered blood-pressure may, it has been alleged, be accepted as safeguards, since on the one hand the intake of the vapour is stopped, and on the other the deportation of the chloroformed blood is lessened. But, inasmuch as the holding of the breath is always followed by one or more vigorous inspirations, which convey large, often fatally large, quantities of chloroform to the medulla, while a lowered blood-pressure and feebly acting heart depress the vitality of the tissues and render the medullary centres more prone to be poisoned, and also increase the danger from vagal inhibition, these conditions are really fraught with grave danger to the chloroformed patient.* And further, even though breath-hold-

* A careful research upon the chemical changes produced in the organs and tissues by the inhalation of chloroform will be found in " Physiologie Travaux du Laboratoire du Ch. Richet," p. 413, 1898, by. Dr. Vidal.

ing may hinder for a moment the additional intake of chloroform vapour, it will in no way prevent the blood from taking up all the chloroform which has already entered the lungs, and this increase in the chloroform tension, since there is no elimination, must make for that overdosage which the breath-holding is assumed to prevent.

THE ADMINISTRATION OF CHLOROFORM.

Many methods have been proposed. They may be classed as (1) those requiring the use of some apparatus or inhaler, and (2) those in which chloroform is given by dropping it upon a towel, handkerchief, lint, etc. In this second class the various plans adopted are commonly grouped under the heading of " The Open Method," although, as will appear from the sequel, while some of the modes of procedure are truly " open," some are not more " open " than when the use of an inhaler is adopted.

Inhalers.—Among the first designed to supply a definite percentage vapour of chloroform were those of Snow,[*] Clover,[†] Sansom,[‡] Squire, and Junker.[§] All of which, except the last, have passed into desuetude. Junker's inhaler has, at the present time, undergone many and important modifications. There is no doubt that the principle which these instruments were constructed to carry out—viz., the regulation in definite proportions of the quantity of chloroform inhaled—is the correct one. No method, indeed, which does not enable the administrator to adopt this principle is a safe or reliable one. Inhalers which supply more or less exactly a definite percentage of chloroform vapour to air are those of Dr. Raphael Dubois, Mr. Vernon Harcourt, Dr. Levy,[||] Professor Waller, Mr. Hirsch,[¶] and the Roth-Dräger apparatus.[**]

DOSIMETRIC INHALERS.

These are of two kinds: those in which the patient inspires air pumped through chloroform—the plenum system; and those

[*] " On Anæsthetics," p. 81.
[†] *Medical Times and Gazette*, Aug. 9, 1862.
[‡] " On Chloroform," p. 127.
[§] *Medical Times and Gazette*, 1867, vol. ii. p. 590.
[||] *Lancet*, May 27, 1905.   [¶] *Ibid.*, Apr. 1, 1916.
[**] These and other apparatus are described and criticised in the **Report** of the Special Chloroform Commission of the British Medical Association, issued in 1911, and published by the British Medical Association at 1s.

in which the patient draws-over air-with-chloroform vapour by
his respiratory effort—the draw-over system.   Of course ulti-
mately the patient has to do work to inhale the mixture, although
in the one case he does so from an atmosphere, and in the other
from a dead space.

THE DUBOIS APPARATUS.*

This apparatus delivers a definite percentage of chloroform
vapour in air to the patient.   As the patient inhales from a
plenum the strength of the vapour is independent of the force
and frequency of the respirations, although the actual amount
of chloroform taken is controlled by these.   Whatever percen-
tage is deemed requisite for the patient is easily obtained by a
simple mechanical arrangement.   The anæsthetist further knows
exactly what strength of vapour he is employing.   As the
apparatus is heavy it is placed upon a firm table near the couch
on which the patient lies.   It consists of a container to which a
definite quantity of chloroform is supplied, a spirit lamp
evaporates the vapour, and this vapour is carried with a
definite quantity of air through a tube to the face-piece.   The
apparatus is worked by a handle, and this when turned initiates
the mechanism by which the chloroform vapour and air are com-
mingled and carried forward to the patient.   By a simple device
the strength of the vapour delivered can be varied.   Thus when
the patient has entered the third degree of narcosis the percen-
tage of chloroform can be decreased.   If for any reason it is
desired to produce a more profound anæsthesia the percentage
can be increased.   Although Dubois' apparatus has been em-
ployed mainly in the physiological laboratory, it possesses great
value as a clinical instrument, as the experience of Dr. Waller and
Dr. Paul Chapman of Hereford has shown.   The type at present
in use is slightly modified from that originally designed, but the
principle remains the same.   It delivers 2 per cent. vapour as
its maximum.

THE VERNON HARCOURT REGULATOR.†

The Vernon Harcourt chloroform regulator is designed to
enable the anæsthetist to retain complete control of the strength

* For a full description of the apparatus see *Anesthésie Physiologique.*
By Dr. Raphael Dubois, Paris, 1894, pp. 106 *et seq.*

† See *British Medical Journal,* July 18, 1903 ; also *British Gynæco-*

of vapour which the patient inhales. This instrument in its present form is the outcome of the painstaking labours of the late Mr. A. Vernon Harcourt, F.R.S., collaborating with the Special Chloroform Committee (B.M.A.), to which he was co-opted a member. The regulator supplies the essentials for a dosimetric inhaler capable of giving definite percentages of chloroform, which are wholly under the control of the anæsthetist. After prolonged investigation it was accepted as satisfactory by the Committee.

DESCRIPTION OF THE APPARATUS.

The Harcourt inhaler supplies a mixture of air and chloroform vapour which is automatically limited to a maximum strength of 2 per cent., and can be diluted at will with

FIG. 55. — Two-necked bottle for chloroform.

additional air down to any lower percentage. The empirical limit of 2 per cent. was imposed by the Committee, as their experiments convinced them that for practically all cases a higher strength of vapour was unnecessary and often dangerous. The inhaler can, of course, be graded for higher percentages.

Into the two-necked bottle chloroform is poured to near the top of the conical part as shown in fig. 55, and two coloured glass beads are dropped into the liquid to indicate when the temperature is within the range 16°–18° C. If the temperature of the chloroform is below 16° both the coloured beads

FIG. 54.—The Vernon Harcourt chloroform regulator. The index indicates 1 per cent.

The inhaler is shown fixed to a stand with an arrangement for warming the chloroform.

logical Journal, May 1904, "Chloroform in Surgical Anæsthesia: The Vernon Harcourt Inhaler," for papers by the present writer dealing at length with the practical and clinical aspects of this invention. The apparatus is made by Messrs. Griffin & Co., of Kingsway, London.

will float ; if it is above 18° both will sink ; in the former case the proportion of chloroform inhaled will be less than the pointer of the stopcock indicates ; in the latter case it will be greater. The proportion is also increased by any agitation of the bottle. During inhalation the chloroform is cooled by evaporation ; its temperature can, however, be kept between 16° and 18° by now and then holding the bottle in the hand till the blue bead has sunk and the red bead is beginning to sink. When the in-haler is mounted upon a stand the temperature of the chloroform can be kept at the required height either by a hot-water bath or
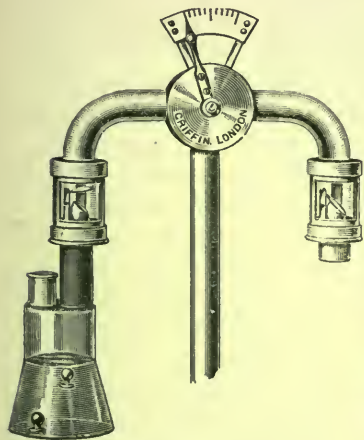
FIG. 56.—Pointer adjusted to give   FIG. 57.—Pointer adjusted to give
2 per cent.   1·4 per cent.

a spirit lamp separated from the bottle by a wire gauze and supported on a movable stand. Even a "night-light" will supply the requisite heat. The dimensions of the bottle have been arrived at after a great deal of experimental work and careful analysis. The diameter of the upper portion has been proportioned to the average rate of human respiration and to the rate of evaporation of chloroform between 16° and 18° C.* To compensate for varying rates of respiration the inlet and outlet of the bottle are placed near together and at some distance from the surface of the

* The first apparatus was graduated for the temperature 13° to 15° C., but for ordinary use it is better to have the bulbs made to indi-cate the temperature mentioned above, otherwise the percentage is liable to fall too low.

liquid, while to compensate for the lowering of the liquid surface
by evaporation the vessel widens as the surface of the chloroform
descends.   The nearness of the two necks one to another, and the
distance between them and the surface of the chloroform, dimi-
nish the variation in the proportion of inhaled air to chloroform
vapour which is caused by abnormally shallow or deep breath-
ing.   When the flow of air is gentle much of it passes in at one
neck and out at the other without reaching the surface of the
chloroform or displacing wholly the mixture of air and chloro-
form which occupies the upper half of the bottle.   On the other
hand, the strong current caused by deep breathing draws out
all the vapour which has been formed and promotes further
evaporation by stirring the surface of the liquid.   With bottles
of the present dimensions this correction is only partial.   If
the rate of breathing is voluntarily reduced to 3 litres a minute
instead of the normal 4 or 5 litres, or raised to 7 or 8 litres a
minute, the proportion of chloroform may be raised to about
2·5, or lowered to about 1·5 per cent.   It would not be difficult
by lengthening the cylindrical part of the bottle to correct more
completely for variations in the rate of breathing.   But it is
believed to be advantageous that the proportion of chloroform
should vary thus, in order that there should be less variation in
the total quantity of chloroform administered.   Two ratios
have to be considered in judging of the probable effect upon a
patient, that of chloroform vapour to air, and that of the mass of
chloroform inhaled to the mass of the body through which it is
distributed.

The stopcock is made so that when the pointer is at the
end of the arc nearest the bottle of chloroform the maximum
quantity is being administered—namely, 2 per. cent.   When
the pointer is at the opposite end only air will be inhaled ;
and when it is midway dilution of the 2 per cent. mixture with
an equal volume of air will make the proportion 1 per cent.
The shorter lines on either side indicate intermediate quantities
—namely, 0·8, 0·6, 0·4, 0·2 per cent. ; and towards the chloro-
form bottle, 1·2, 1·4, 1·6, 1·8 per cent.

The valves on the two branches prevent the entrance into
the apparatus of expired air, and also serve to show whether
the stopcock is working correctly.   Only one valve opens when
the pointer is at either end of the scale, both equally when the
pointer is midway, and for all other positions one valve opens

more and the other less, in the degree indicated by the position of the pointer on the scale. The movement of these valves shows also how full and regular the breathing is, and the slight click which they make conveys this information to the ears when the eyes are otherwise occupied.

It is generally found that beginning with the pointer at o·2 per cent., and moving it on towards the chloroform bottle, at

FIG. 58.—Flanged face-piece (Dr. Dudley Buxton's pattern).

the rate of one division about every half-minute up to 1·6 per cent. or 1·8 per cent., produces narcosis as quickly as is desirable.

For the maintenance of narcosis it is found that 1 per cent. or even less will be sufficient. The stopcock can be moved by a touch of the finger so as to increase or diminish the percentage.

If by fall of temperature, or agitation of the bottle, the yield of chloroform is diminished, or increased, this may be allowed for at once by a movement of the stopcock.

The face-piece is provided with an **expiratory valve** unless the valve is fixed on the upright stem of the inhaler (Plate V.). It is usually connected by about 20 inches of half-inch rubber tubing, the inhaler being supported on a stand, or attached to a sling passing round the neck of the administrator as shown in Plate V., or it can be attached to the back of the patient's bed.

FIG. 59.
Valve chamber.

The mask is made of solid toughened rubber, fitted with

a rubber air-cushion. In practice it is found advisable to nearly
fill this air cushion with water, adding enough air to produce
moderate distension. It can be washed, or placed in hot water,
and as it then becomes plastic the shape can easily be modified,
if required, so as better to fit the patient's face. I have had
a flanged mask made (fig. 58) which materially facilitates keeping
it accurately applied to the face and prevents inleakage of air.

Certain cases may occur in which a higher percentage is
required than that afforded by the apparatus as above described.
For increasing the strength of the vapour inhaled a tube (fig. 60)
is provided which fits into the open neck of the bottle, raising
the possible maximum dose to 2·5 per cent. if this is desired. At
intermediate positions of the pointer the percentage will be
increased in the same proportion as the maximum. Owing to
the unavoidable limitations of accuracy imposed by the glass-
blower's art the ingress neck of the chloroform bottle is not
absolutely uniform, so to correct this the most recent form of
bottle is fitted with a metal collar fixed into the ingress neck,
which then is quite true to scale.

No chloroform evaporates excepting that which is inhaled
by the patient ; and only that which is exhaled passes into the
air of the room.

Use of the inhaler.—The apparatus must be carefully examined
to see the parts are adjusted, and the administrator should inhale,
or incline the instrument sideways, to see that the valves are
working properly. About 2 oz. of chloroform should be poured
in as high as the waist of the conical bottle and the beads in-
troduced. The face mask should then be carefully applied.
This is best done when the head is turned to one side. Breathing
taking place freely and the air inlet valve and expiry valve work-
ing properly, the face-piece should be grasped with the left hand,
while the lower jaw is pressed forward by the right hand placed
behind its angle. Firm pressure is necessary, as absolute co-adap-
tation of the mask to the patient's face is essential. If the
pressure used is equal over the whole area of the face the patient
will not complain. It is a common fault to allow air to enter by the
sides of the bridge of the nose. Absolute fitting of the face-piece
having been secured, the strength of the vapour may be gradually
increased by turning the pointer. This is done slowly, but, unless
the patient is restless and struggles, not very slowly. Struggling
is an indication for lessening the strength of the vapour, but not

PLATE V.

Vernon Harcourt chloroform regulator, to which is fixed a flexible tube connecting the inhaler with the face-piece, also oxygen connexion. The manner of holding the face-piece is indicated, and the position of the expiratory valve attached above the flexible tube and opposite oxygen inlet. The oxygen cylinder is shown.

for the removal of the face-piece unless duskiness supervenes.
When anæsthesia is attained, the usual signs being relied upon,
its maintenance can be effected in most cases with 1·5, 1, or even
0·5 per cent., according to the physique of the patient and the
requirements of the operation. After prolonged administration
slight duskiness may appear, and in this case the mask may be
lifted for a few breaths and then replaced. A better plan,
however, is to have a supply of oxygen (see Plate V.) which by
a simple adjustment can enter the apparatus throughout the
inhalation. Under ordinary circumstances a very small stream
is required, but at times the amount given should be increased.
The indications for this are the appearance of the face and super-
vention of shock.

It has been pointed out that shaking of the chloroform bottle
and variations in the rate and force of breathing alter to an
appreciable extent the actual amount of chloro-
form inhaled. The shaking of the bottle need
never occur, especially if the inhaler is removed
from the patient's face while he is lifted on
to the operating-table, or when his posture has
to be changed during the operation. The
variations in the rhythm of respiration occur chiefly during the
induction, and in practice give rise to no difficulty. In using
this, as in the case of any inhaler, the anæsthetist must of
course be guided by the usual signs of chloroform narcosis,
and when this is too profound the indicator should be turned
to 1 per cent., or whatever strength of vapour seems desirable.
It cannot be too strongly insisted upon that the Vernon
Harcourt regulator is only a means to an end. It supplies a
fairly accurate method of regulating the percentage of chloro-
form presented to the patient, but it does not, nor can any
inhaler, abrogate the necessity for a competent knowledge of the
action of chloroform on the human subject and experience in
administering that anæsthetic. *The apparatus need not, and
must not, detach the chloroformist's attention from his patient's
condition ;* it merely enables him to increase or decrease the
dose of chloroform as may be necessary. Observation of the
patient's condition will indicate when this necessity arises.
In using the inhaler, care should be taken that there is accurate
apposition of the mask to the face, otherwise the vapour supplied
will be below the necessary 2 per cent. and failure may result.

FIG. 60.
Increase of per-
centage tube.

A wet towel or roll of wet gauze will in some cases, *e.g.* in edentulous patients, assist in securing air exclusion. This is laid over the chin and folded up in the hand, holding the mask in such a way as to prevent air being sucked in around the air pad. The air pad should always be well inflated before use. It is also necessary to see that the valves are acting and the expiry valve is not covered up. The inspiry valves should be in a horizontal
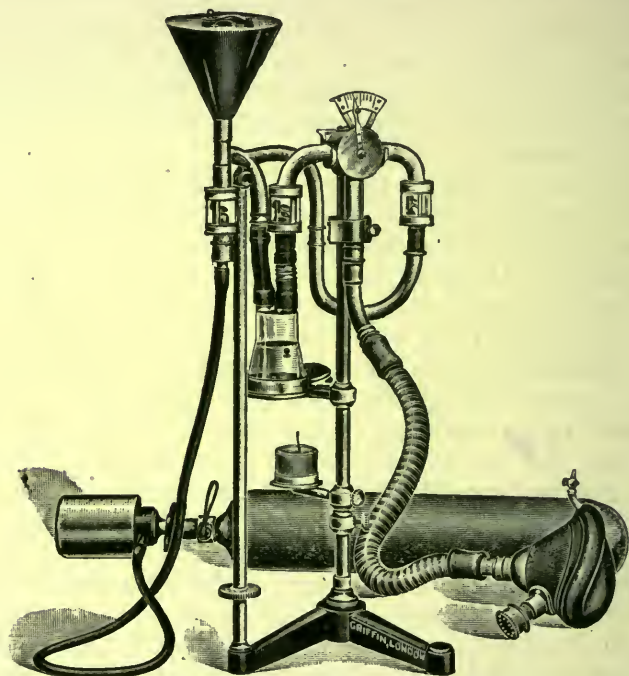
FIG. 61.—The Vernon Harcourt inhaler fitted with a constant supply of oxygen from a cylinder of compressed oxygen arranged as a " plenum " inhaler.

plane, and the whole apparatus placed out of the way of the surgeon and his assistants.

Steadiness is certainly obtained by fixing the body of the apparatus to a stand placed on a table or fixed to the operating-table, and connecting it as above by means of tubing with the face-piece (see fig. 54). When the operation is on the neck or upper part of the trunk, it is better to have the expiratory valve fixed in a connexion joining the tube and face-piece with the

vertical stem of the inhaler. This prevents exhalations passing over the area of operation. In this case the valve aperture in the face-piece, if one exists, can be closed with a cork. (This arrangement is shown in Plate V.)

I am fully convinced that oxygen should be employed whenever a general anæsthetic is in use, and this is especially true of chloroform when given for severe operations involving shock. It is to be used as an adjuvant, and never to such an extent as to produce apnœa. Mr. Harcourt has devised a somewhat complicated addition to his regulator which converts it into a plenum inhaler and permits a very free supply of oxygen. It is shown in figs. 61 and 62.

As *warmed* oxygen is far more efficacious than cold, the best plan is to allow the gas to pass from the cylinder into a worm of tubing through a warming chamber heated by water or an electric heater and then out through pressure tubing to its connexion with the inhaler as shown in Plate V. This plan allows air as well as oxygen to be breathed, a matter of importance. The entrance of oxygen lowers the percentage of chloroform vapour so that the increase tube may be required.

FIG. 62.—The Vernon Harcourt inhaler adapted for a " plenum " inhaler.

In operations upon the air-passages propulsion of the chloroform and air mixture into the mouth or nose is necessary, and by attaching a large hand-ball or foot-bellows to the air-supply tube shown in fig. 62, and substituting a mouth or nasal catheter for the face-piece an *ad plenum* constant supply of the air-chloroform mixture can be secured.

Speaking from an experience of some years, and several thousand cases, many of the gravest character, I may say I have found the inhaler fulfils all the purposes for which it was constructed. It supplies a 2 per cent. vapour, although capable of giving a 2·5 per cent., but 2 per cent. in practically all cases will induce profound narcosis. The experience gained in war surgery has, however, shown that there are some soldiers who need

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the use of a 3 per cent. for rapid induction, although such a strength needs especial watchfulness during its use. The apparatus is easy to manage, and when the technique is once learned it proves reliable and satisfactory. There have been no dangerous symptoms due to the anæsthetic in the cases in which I have used the inhaler, and no failures. It has been increasingly rare for me to have to employ any percentage higher than that afforded by the inhaler ; and even in the few instances in which I have replaced the inhaler by another, the necessity has usually arisen from the difficulty experienced in making the face-piece fit accurately.

DR. LEVY'S REGULATING INHALER.*

This, like the Vernon Harcourt regulator, is devised upon the " draw-over " principle, but differs in several particulars, which may be summarised as follows :—

(i) The range of the available strength of vapour extends up to 4 per cent.

(ii) The principle of the water-bath is applied to the regulation of the temperature of the chloroform, which therefore requires no active attention.

(iii) It is designed for use only when fixed to a table or other support, in order to obviate the possibility of any error arising from accidental agitation of the chloroform.

(iv) The percentages of vapour are accurately controlled even under the diverse conditions of draught consequent upon different types of breathing. A difficulty occurs under ordinary conditions of aspiration over a surface of chloroform, in that a slow current of air, such as would result from a faint inspiration, takes up a larger proportion of vapour than does that resulting from breathing of a more vigorous type. An adjustment is · brought about in this instrument by applying a twofold principle. Firstly, only a fraction of the inspired atmosphere passes through the chloroform container ; this vapour-laden portion is charged

* *Lancet*, May 27, 1905. Cf. *Medico-Chir. Soc. Trans.*, vol. lxxxviii. p. 673.

CHLOROFORM.to a high percentage, and it naturally moves at a slower rate than would the total inspiration. Such fractions of inspirations exhibit relatively less change of composition for varied inspirations than would be the case if the whole of the inspired air passed over the chloroform. The complement of pure air is drawn through a large aperture which is permanently open, and in this way the percentages of vapour in the mixture are approximated. Secondly, the "chloroform current" traverses a series of tubes and passages, and in consequence undergoes a certain retardation which tends to be more pronounced during weak suction; the influx of pure air through a simple aperture not being retarded to the same extent, it follows that the dilution becomes greater during faint inspirations. This supplementary process supplies the finishing touch, which renders the percentages practically identical for all forces of suction commonly found under chloroform narcosis.

The body of the inhaler consists largely of a vessel which is filled with water at a temperature of 104° F., and the chloroform container forms a part of the cover of this vessel; the supply of air to the chloroform is controlled by a tap which is manipulated by an index hand, and the position of this indicates on a scale plate the percentage being delivered, a simple form of correction being applied for any temperature of water between 104°—52° F. A length of wide-bore aluminium tubing and a double junction serve to connect the body with the face-piece. Two hinged aluminium valves, inspiratory and expiratory, complete the apparatus, which has generally been constructed with a view of presenting the least possible resistance to the passage of the inspired air.

Mr. Hirsch's Simplified Chloroform Inhaler.

M. Regnard showed an apparatus at the Seventeenth International Medical Congress, which he claimed gave definite percentages of chloroform. Professor A. D. Waller, F.R.S., modified this and corrected some imperfections in the original form, making the inhaler accurate and manageable. Basing his plan upon this model, Mr. C. J. Hirsch * has produced an excellent and simplified dosimetric chloroform inhaler which is described

* *Lancet*, April 1, 1916.

below. I have used both Professor Waller's and Mr. Hirsch's apparatus and can vouch for their value.

Mr. Hirsch's model consists of a metal cylinder divided by a thin domed false bottom into two chambers. The lower one is coned to take an ordinary gas face-piece, and is provided with a movable angle connexion for use when the patient is on his side or face. Various pieces are made with different angles
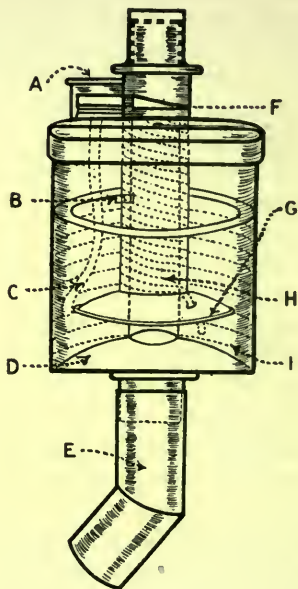
FIG. 63.—A, inlet for chloroform addition. B, chloroform by-pass to air chamber. C, chloroform tube. D, hollow dome. E, detachable tubing for fixing to respirator. F, port or air inlet. G, baffle plate. H, absorbent wick for chloroform around central cone. I, absorbent wick around walls of chamber.

so that the " pot " can be kept fairly vertical, irrespective of the patient's position. A central tube passes through the lid and upper chamber, terminating in the false bottom, and conveys air directly to the face-piece. This central tube is surrounded by an air cone which is expanded below over the false bottom in a baffle plate, so as to distribute the air equally over the anæsthetic. A by-pass traverses the upper chamber through the cone and projects into the air tube. The air cone is provided with an

opening or port, admitting air to the upper or chloroform chamber. The size of the port is regulated by a movable collar on the lid, and an indicator shows the percentage of chloroform which is passing to the face-piece. The upper chamber is surrounded inside with wick, and also has wick round the inner cone. Both wicks touch the bottom of the upper chamber, the last mentioned by passing through a hole in the baffle plate. The lid is removable, but to save taking it off during the administration of the anæsthetic, a screw-on cap in the lid permits of the addition of chloroform to the upper chamber. The wicks can be removed, and the whole apparatus sterilised, and after this it must be thoroughly dried before the wicks are replaced.

To use the inhaler, twelve drachms of chloroform are placed in the upper chamber, which saturates both wicks and leaves a layer on the false bottom below the baffle plate, but not touching it. Care must be taken that the chloroform does not reach as high as the baffle plate, otherwise the apparatus will not work correctly. The indicator is put to zero (port closed). An ordinary gas face-piece is attached to the coned end, either directly if the patient is on his back, or if in another position by means of one of the angle pieces. The face-piece is then adjusted to the patient's face, so that the only admission of air is by the air tube. Pure air is then breathed. As the port is opened chloroform vapour is drawn through the by-pass in the same way as air is sucked in by a Bunsen burner or a Fletcher gas-stove. The expirations of the patient maintain a constant temperature in the chloroform chamber, and from actual experiments at that temperature the dial on the lid is graduated to show the percentage being inhaled. In use it is found advisable to start with the port closed, indicator at zero, and to take ten to fifteen minutes in passing gradually to 2·5 per cent. when surgical anæsthesia is generally produced. A higher percentage is rarely if ever needed. Anæsthesia, when obtained, can be maintained at from 1 to 2 per cent.

Oxygen can be given at the same time by slipping a pewter tube connected with an oxygen cylinder into the air-tube.

After induction with chloroform, ether can be substituted and anæsthesia thus maintained. With the indicator at full, over 10 per cent. ether is obtained ; if a higher percentage is needed four layers of gauze can be attached to the air tube and additional ether dropped on. A special frame is provided for this purpose. By this means any depth of ether anæsthesia can be obtained.

PLENUM INHALERS.

The inhalers constructed upon the principle of mixing air with chloroform vapour in definite proportions, the air being driven through the chloroform and so presenting a vapour to the patient which he aspires, are best represented by Dubois' anæsthetic machine (see above, p. 249), by Dr. Waller's * balance inhaler, by the late Dr. Alcock's inhaler † and by the Roth Dräger inhaler. These supply definite percentages, and are more adapted for hospital practice. The Roth-Dräger possesses
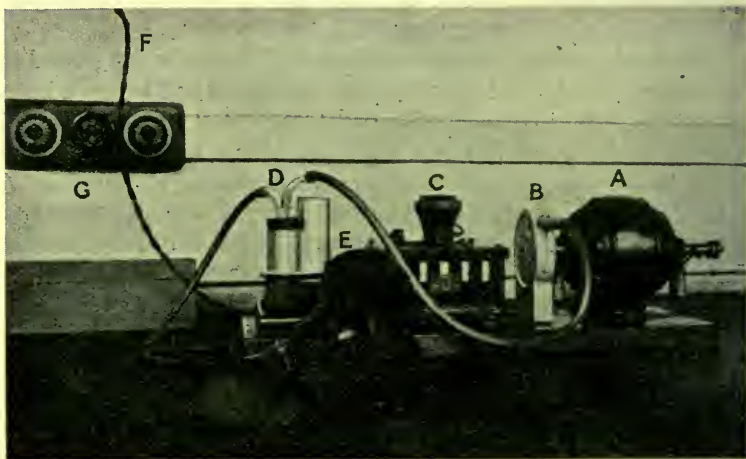
FIG. 64.—Mr. Hobday's electric motor apparatus for the administration of anæsthetics.

A, Electric motor.   B, The fan and tube attachments.   C, The contact breaker and regulator.   D, The specially constructed bottle containing the anæsthetic.   E, The inhaler. F, Wire to be attached to an electric lamp bracket or plug in wall.   G, Switch.

the advantage of mixing oxygen with the air and is a very useful, although elaborate, apparatus. It, however, can supply percentages of chloroform far above the safety limit, and in this may prove dangerous. There is attached to it an ether-supply enabling the anæsthetist to use at will one or other or a combination of these anæsthetics. Junker's inhaler, constructed also upon the " plenum " system, is portable, but is only approximately accurate as a means of giving definite percentages, and

* *Trans. Roy. Med.-Chir. Soc.*, vol. lxxxviii. pp. 685 *et seq.* ; *Science Progress*, vol. ii. p. 621.

† *Brit. Med. Jour.*, Aug. 15, 1908, and Feb. 6, 1909.

its use is not free from danger.   As is indicated above, the Vernon
Harcourt regulator can be used as a plenum inhaler.

Mr. Hobday * has invented a very useful form of dosimetric
chloroform inhaler which can be used for animals or human
beings by supplying suitable face-pieces. Air is driven over
chloroform kept at one level by a simple device, the strength
of vapour being capable of exact adjustment. The grading
has been carefully worked out by Mr. W. Legge Symes.   I
have used this apparatus for dogs, but not for human beings.
It is at once simple and reliable.   It is actuated by a motor
(fig. 64).

Junker's Chloroform Inhaler.

This **inhaler** has been modified by many persons. Designed
for use with " methylene," the apparatus is now used for chloro-
form.

As originally made it consisted of a glass bottle fitted with
a metal mount on which is
screwed a metal cap, and to
this are attached two tubes,
one for ingress of air, one for
egress of chloroform vapour
and air ; a Richardson's hand
ball-bellows and a vulcanite
face-piece with tubes which
connect the bottle with the
bellows and face-piece.   Half
an ounce of chloroform is placed

Fig. 65.—Glass face-piece (Dr.
Dudley Buxton).

in the bottle, and the top screwed on. To the ingress hole is attached
a long metal tube extending from the metal cap to below the level
of the chloroform, so that when the ball-bellows is compressed,
air passes down this tube and ascends through the chloroform
taking up vapour.   Finally the vapour escapes by the egress tube
into the vulcanite face-piece from which the patient inhales.

In my original modification of this apparatus an ounce of
chloroform is poured into a bottle † through a funnel-shaped

* *Canine and Feline Surgery*, by F. R. G. Hobday, F.R.C.I.V.S., F.R.S.E.,
pp. 33 *et seq.*

† The bottle I use is somewhat larger than the original pattern, as this
gives the administrator a greater control over the chloroform.   He can
employ as dilute a vapour as possible, but can give a stronger one should
occasion demand it.   In the shorter bottles, if the upper surface of the

opening fixed in a screw top. A foot-bellows can be used instead
of the hand ball-bellows. It is fixed by straps, one of which slips
over the toes, while the other receives the heel in a long loop.
When the foot presses lightly, the air in the bellows is forced
through the tube into the bottle, thence through another and
shorter tube to a face-piece. The addition of the pressure ball
is for equalising the stream of air and the avoidance of splashing,
while it converts the intermittent into a constant supply of
vapour. It is important not to put more than an ounce into
the bottle at once, unless a large bottle is employed, and not to
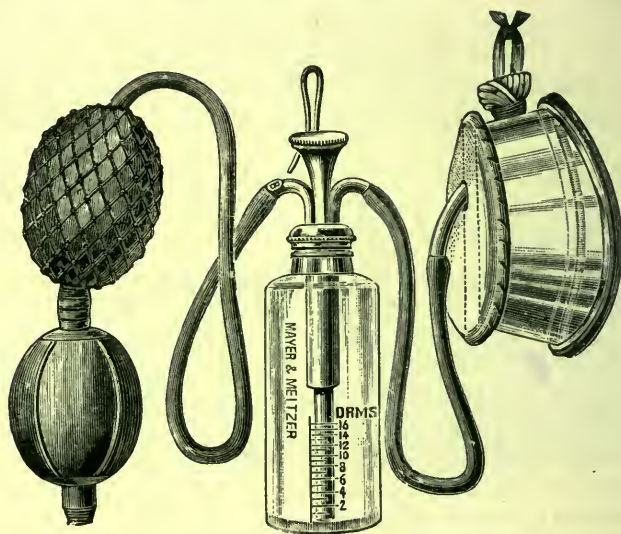
Fig. 66.—Dr. Dudley Buxton's improved chloroform inhaler. [The bottle
as shown in the picture is too small and the tubes too short.]

pump in air spasmodically or too forcibly, otherwise chloroform
may be driven through the system of tubes into the face-piece.
Even if this should not happen, a strong blast of chloro-
form-impregnated air is very unpleasant and deleterious if
allowed to impinge upon the face. The longer tube in the bottle,
along which the entering air travels (afferent tube), should have
its lower extremity tipped with some non-conductor of heat, such

chloroform is within a certain distance of the entry of the egress tube,
liquid chloroform is forced up this tube. When this has once been done
by vigorous compressions of the hand-bellows, syphon action is established
and the contents of the bottle are pumped over, with dangerous results.

as wood or bone, to prevent freezing and blocking of the tube ; and the exit tube (efferent tube) should be so constructed that in no position of the apparatus can liquid chloroform enter it. When the bottle has become nearly empty, the mill-headed stopper which closes the funnel is removed and more chloroform added ; thus the apparatus need never be unhooked from the administrator's coat, and the top never unscrewed until the administration is over, when the bottle should be emptied and cleaned.

In fig. 66 is shown the apparatus I have now employed for
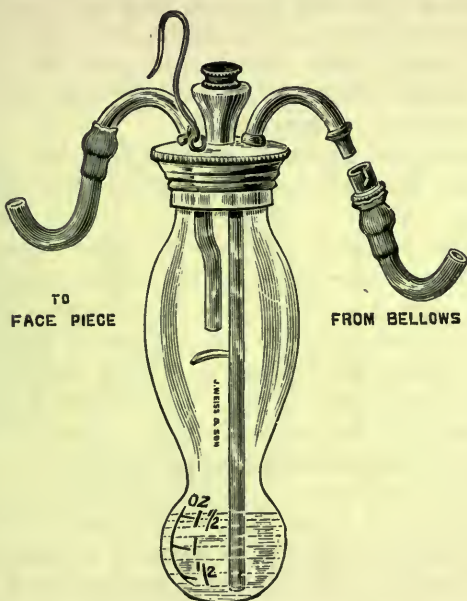
FIG. 67.—Chloroform bottle for Junker's inhaler (Carter Braine).*

some years, and this I have found to answer better than any of the older patterns. It consists of a somewhat larger Junker's bottle than usually supplied. The Skinner's mask is replaced by a glass face-piece, to which is fixed a metal rim carrying the air-chloroform supply tube, and this delivers into a perforated tube running from back to front of the metal frame. There is a hinged rim which can be raised to allow a piece of lint or domett being placed over the opening on the upper aspect of the mask. When this rim is shut down it locks

* I am indebted to Mr. Carter Braine for the woodcut.

itself and keeps the lint in position. This apparatus can be rendered sterile by boiling. The danger which existed in the older forms of the apparatus, of liquid chloroform entering the efferent tube and so passing into the face-piece, can be avoided by bringing down the efferent tube as an ensheathing tube over the afferent tube. This will prevent chloroform entering the tubes, even if the bottle is inverted or laid upon its side. There must be at least an inch interval between the surface of the chloroform and the opening of the efferent tube, to avoid the possibility of fluid being forced or syphoned along the efferent tube. The bottle shown in the figure, although graduated for two ounces, should never contain more than one ounce, otherwise the requisite interval between the chloroform and the ensheathing tube is not maintained.

The bottle figured above is one devised by Mr. Carter Braine to obviate the danger of liquid chloroform entering the efferent tube (fig. 67).

There is also a danger, if the indiarubber tubing from the bellows, and that to the face-piece, the afferent and efferent tubes respectively, are attached to the wrong tubes on the bottle, that the chloroform may be pumped out of the bottle along the efferent tube to the face-piece. This is more perilous when a mouth- or nasal-tube is in use. The ingress and egress tubes should be carefully marked distinctively to avoid this mistake. Several deaths have resulted during the use of the older form of apparatus from chloroform being injected into the patient's larynx through the nasal tube. This nasal tube—a flexible tube like a catheter—may be replaced by a metal mouth tube shown in fig. 68, C. *The apparatus should always be tested before use to ensure the proper arrangement of the tubes.*

When chloroform is administered for operations about the mouth or nose, *e.g.*, removal of an upper jaw, the tongue, etc., the anæsthesia having been obtained by chloroform is best maintained by fitting the efferent tube of a Junker's inhaler (*i.e.*, the tube not connected with the bellows) to a catheter, and, either passing the catheter through the nostril so that the end hangs down behind the soft palate and permits the vapour to enter the larynx, or else holding the catheter in the mouth. When a preliminary tracheotomy has to be performed a Trendelenburg's or Hahn's tube may be used, the catheter may be held over the external opening of the tube, and

chloroform vapour so allowed to enter the trachea. If the upper opening of the larynx is plugged, the Trendelenburg's or Hahn's tube may be replaced by an ordinary tracheotomy tube. This plan I think is best. The alternative plan of using Crile's tubes is described above.

Another plan is to connect the tube with the gag (Hewitt) and pump the vapour through this tube into the mouth.

Junker's inhaler has been modified by Messrs. Krohne and Sesemann, the original makers (fig. 68). The bottle and tube remain the same, but the face-piece is replaced by a Skinner's mask (see fig. 69) so constructed that the chloroform vapour
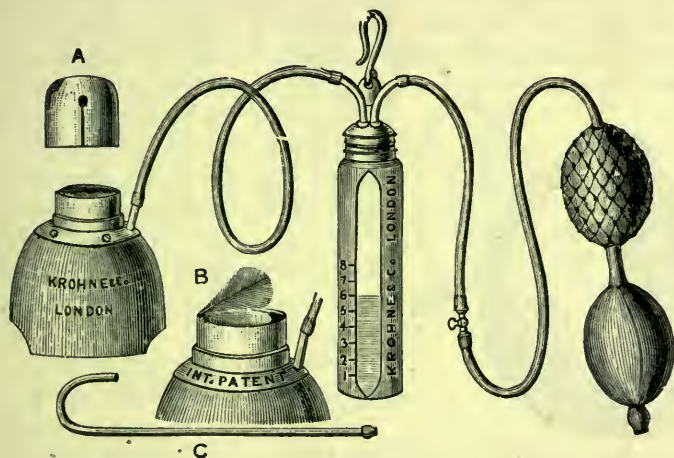
FIG. 68.—Krohne and Sesemann's feather respiration register.

escapes by a series of holes in the midrib of the frame as in the author's face-piece. The frame is covered by a removable flannel cap. By this contrivance the face-piece is pervaded with vapour instead of a puff of chloroform being intermittently propelled against the face. The advantages of the flannel cap are (i) its permitting free breathing through its substance, (ii) the patient obtains a free air-supply, and further, the administrator can, by placing his hand over the mask, feel whether or not a sufficient blast of air is being expired. It is cleanly, as it can be removed easily and washed.

The feather seen in fig. 68 at B is intended as a guide to the administrator, its movements being a register of the expi-

rations and inspirations of the patient.   I think it is not wise to
trust to any mechanical test of respiration, however ingenious ;
I prefer therefore to use either the glass mask or flannel cap.
Mr. Krohne has further elaborated the apparatus so as to permit
great dilution of the vapour.   Thus with the most recent pattern
of the inhaler $\mathfrak{m}$ i can be given and the dose gradually increased.
This is effected in the following way.   The afferent or air tube,
instead of being provided with one compression and one resis-
tance ball as in Richardson's bellows, has three indiarubber
balls of different sizes placed at the hand end of the tube.   These
are made of such capacity that known quantities of air are pro-
pelled into the chloroform bottle, according as the large, medium,
or small ball is squeezed by the hand.   This contrivance is of
course only approximately accurate.   The actual amount of
chloroform taken up by the air which traverses the chloroform
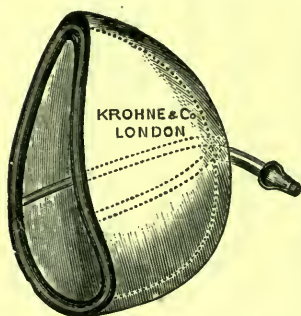
FIG. 69.—Flannel cap for
use with Krohne's Junker
inhaler.

bottle will be influenced by the
depth of the chloroform in the
bottle, the rate and vigour of com-
pression, and the temperature of the
room and of the bottle and the con-
tained chloroform.   It is increased
by shaking the bottle and by splashing
the chloroform.

The assumption that for every
squeeze of one or other of the
pressure balls one minim or less of
chloroform is volatilised is probably
inaccurate when the method is em-
ployed in surgery, although it may
be approximately true under the
controlled conditions of a laboratory.   Both Waller and
Chapman have proved that as strong a vapour as 6 per
cent. may be delivered to the patient when Junker's inhaler is
employed.

Messrs. Mayer and Phelps have devised a safety-bottle for use
with the Junker's inhaler which is excellent and prevents many
of the accidents referred to above.   Twin bottles are arranged
in such a way that, however the tubes are connected, the chloro-
form passes from one to the other bottle, and so cannot be in-
jected as a liquid into the patient's air-passages (see fig. 70).

METHODS WHEN A DOSIMETRIC APPARATUS IS NOT USED.

Many persons prefer to rely upon simpler methods in giving chloroform. The obvious disadvantage of such plans is that during their use even the most expert cannot tell what percentage of chloroform the patient is taking, and so must rely solely upon the effects of the anæsthetic on the patient as observed
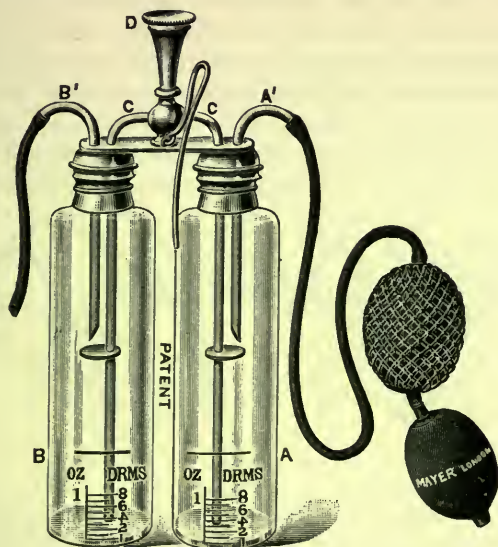
FIG. 70.—The Chiron Chloroform Bottle.

A and B are twin bottles connected by their inlet tubes c. c. When in use the bellows are attached to one of the outlet tubes A′ or B′. If attached to A′, when air is pumped in the liquid chloroform in bottle A is driven by the inlet tube c. c. into bottle B, with the result that bottle B works normally as a supply of chloroform vapour, the air being driven through the inlet tube c. c. and vapour out by the outlet tube B′. The same effect follows if the bellows are attached to B′, only in this case the bottle A act ;as the supply and the vapour passes to the patient through the efferent tube A′. NOT MORE THAN TWO OUNCES of chloroform must be introduced into the apparatus. This applies to all bottles employed with the Junker inhaler.

by him. Thus, although the expert chloroformist may employ such a method without grave risk, one less experienced is liable to give too much or too little of the anæsthetic, being at times either unobservant, or unable to understand the meaning of such changes in the patient's condition as he may notice.

The methods usually employed may be described briefly as the "Scotch," the Hyderabad (which is a convenient adaptation of the first-named and especially useful in hot climates),

and the plan of dropping chloroform from the drop-bottle upon a mask or improvised face-piece.

The Scotch method was described by Simpson in the following words :—

" When used for surgical purposes, perhaps it will be most easily given upon a handkerchief, gathered up into a cuplike form in the hand of the exhibitor, and the open end of the cup placed over the nose and mouth of the patient. For the first inspiration or two, it should be held at the distance of half an inch or so from the face, and then more and more closely applied to it. To ensure a rapid and perfect anæsthetic effect—more especially when the operation is to be severe—one or two teaspoonfuls of the chloroform should be at once placed upon the hollow of the handkerchief and immediately held to the face of
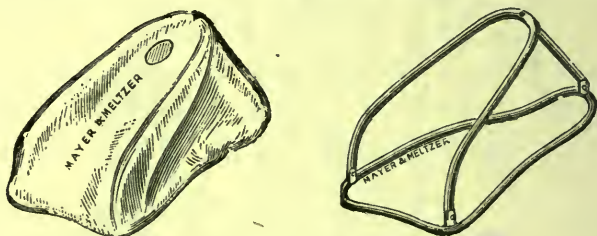
FIG. ·71.—Skinner's frame for chloroform.

the patient. Generally a snoring sleep speedily supervenes ; and when it does so, it is a perfect test of the superinduction of complete insensibility. But a patient may be quite anæsthetic without this symptom supervening."*

The late Lord Lister thus described the Scotch method :— A common towel is arranged so as to form a square of six folds, and enough chloroform is poured upon it to wet an area the size of a hand's palm, the precise quantity poured on not being a matter of any consequence. The patient is instructed to close his eyes to protect them from the irritating vapour, and the towel is then held as near to the face as can be borne without inconvenience. More chloroform is added from time to time as occasion requires. Lord Lister suggests the following simple way of devising a chloroform mask :—The corner of the towel pursed up systematically into a concave mask to cover the mouth and nose, by pinching it together at such a distance from the corner

* Simpson's " Anæsthesia," p. 159.

that, when the pinched-up part is held over the root of the nose, the corner extends freely to the point of the chin. " The cap formed in this manner being so arranged upon the face, chloroform is gradually dropped upon it till the greater part of it is soaked, the edges being left dry to avoid irritation of the skin by the liquid, and the moist condition is maintained by frequently dropping on the convex surface until the requisite physiological effects are produced." The corner of a towel drawn through a safety-pin makes a mask as described by Lord Lister.

The method in which a drop-bottle is employed requires either the use of an extemporised inhaler, such as that suggested
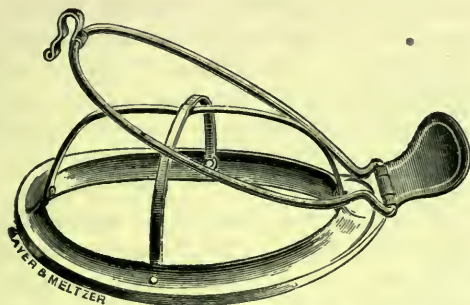
FIG. 72.—The Schimmelbusch mask.

by Lord Lister, or of a mask. Those described below are the best known.

Masks.—The Skinner's mask figured above (fig. 71) is a con venient form. It consists of a wire frame on which is stretched a *single* layer of flannel, domett, or lint. The chloroform is allowed to fall *guttatim* upon the upper surface.

An excellent form of mask now commonly used is due to Schimmelbusch. It consists of a metal frame on which are fixed two bent semicircles at right angles. These fit into the frame when not in use, but when used, open out and form a cup over which is stretched a *single* layer of lint kept in position by the hinged rim, which is attached to the frame. It is used with a drop-bottle, or chloroform is sprinkled over it (fig. 72).

The Hyderabad cone, as devised by the late Lieut.-Colonel Lawrie, I.M.S. (fig. 73), is essentially a calico mask with some cotton-wool in its apex and its sides strengthened by thin strips of wood. Into this two drachms of chloroform are poured, and the mask held a little way from the face until the patient is ac-

customed to the vapour, and his nervousness has passed away.
The mask is then brought gradually nearer to the face. Chloro-
form is poured on from time to time as required. To do this
the cone is inverted and a drachm of chloroform poured into it.

The administration.—Whatever method is employed the same
result is aimed at, and the rules guiding the administrator, as
well as the phenomena shown by the patient during inhalation,
are so essentially similar that it is proposed to consider the course
of narcosis under chloroform in general, noting later such special
points as may need further elucidation in relation to special
methods.

The patient should be carefully prepared, for this is perhaps
even more important in the case of chloroform than in that of
any other anæsthetic. Vomiting nearly always occurs during
the induction of anæsthesia when the stomach contains food,
and when the bowels have not been properly regulated. Asso-
ciated with vomiting are lowering of the blood-pressure and
increased liability to syncope.

Posture.—The patient must be placed recumbent, with all
his clothing absolutely loose. The sitting posture was believed
by Snow to be a safe one for chloroform narcosis, but in view
of our present knowledge it seems highly important that, even
for short operations, the chloroformist should insist upon the
recumbent posture. An attempt has been made recently to
re-introduce the sitting posture during chloroform narcosis,
but its advocates appear to ignore the well-authenticated reasons
which negative such a position. It is perfectly true that *after
induction*, when the patient's circulation has adjusted itself to the
changed conditions, and if the narcosis is not profound, a patient
can without serious danger be propped up to a height convenient
for the surgeon. Even this procedure is not entirely devoid of
risk, and the wiser plan is to induce anæsthesia with ether and
rely upon chloroform for maintaining anæsthesia during the
operation. Whenever the exigencies of the operation permit,
the head should be placed at a lower level than the abdomen.
In the first degree of narcosis the head may be allowed to be
somewhat higher, as most persons, more especially the stout,
feel uncomfortable and may find breathing difficult if the head is
very low. The pillows must be so arranged that the head is
slightly extended upon the trunk, never flexed with the chin
resting upon the breast. Over-extension tends to cause dropping

of the chin with falling back of the tongue, while extreme flexion interferes with natural respiration. When the second degree of narcosis is reached, the head should be lowered and the face turned to the side.

The inhalation.—If a preliminary hypodermic injection is to be given it is introduced an hour and a half before the chloroform is inhaled, but in the following account the assumption is made that no such course has been adopted. The patient, having been reassured, is asked to breathe naturally and not to hold his breath. A moment or two spent in demonstrating how this is done is generally time saved. In whatever manner the chloroform is given, whether from an inhaler, or from a Skinner's
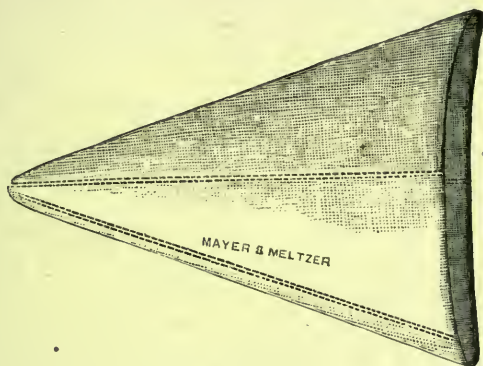
FIG. 73.—Hyderabad cone.

or other mask associated with use of a drop-bottle, as by the open method, the greatest care must be taken to give a dilute vapour at the commencement of the administration. The mask, or lint, should never be placed close to the face immediately, but held at a distance of a few inches, being gradually approximated. There must always be a free flow of air entering round the frame, and expiration must be unhampered when the open method is in use. As chloroform may drop on the skin, the chin, cheeks and nose should be smeared with vaseline and the eyes protected by a piece of lint. Coughing, holding the breath, struggling, nearly always arise from too strong a vapour being presented to the patient. Soon the strength of the vapour can be increased. The patient becomes restless, talks nonsense, tries to move. Struggling may be very violent, especially in the

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case of muscular, of athletic, and also of alcoholic persons. It is always a dangerous complication, as the muscles become spasmodically contracted, interfering with breathing and imposing a great strain upon the heart.

The chloroform must be withheld until breathing is normal again, and the patient must be prevented from hurting himself and from getting off the table. Care and tact in doing this are essential, as violence in restraining the patient provokes fresh violence on his part. Continuity of inhalation is essential, so that unless the breathing has actually stopped through spasm or voluntary breath-holding the mask should not be removed, while if its removal is imperative owing to interference with respiration, every effort must be made when it is replaced that the strength of chloroform then given is not higher than it was before the mask was lifted. The pupils now gradually dilate and the eyeballs roll from side to side. As the stage of excitement becomes more pronounced the breathing must be carefully watched. The amount of excitement shown varies, not only with the individual patient, the strong and muscular evincing most, but also with the method employed. With dilute vapours at the commencement of inhalation, for example, when the Vernon Harcourt regulator is used the excitement stage is usually very brief and ill-defined or absent. Even when no previously known obstruction exists, such as nasal stenosis, buccal growths, enlarged tonsils, pharyngeal or laryngeal tumours, interference with respiration during inhalation may occur from spasm of the masseters, insucking of the lips, laryngeal spasm (see Complications), epistaxis, vomiting, falling back of the tongue, or fixation of the chest by muscular spasm. Such interference with respiration, as it introduces some degree of asphyxia into the case, is pregnant with danger, and must be met at once by removing the mask if a non-dosimetric method is in use. If the obstruction is in the upper air-passages, opening the mouth with a gag or separation of the lips with the finger will usually enable the patient to take one or two inspirations, which will probably tide him over the period in which muscular spasm exists. The mouth and upper pharynx must, of course, be examined with the finger, if there is any reason to expect the presence of foreign bodies in the buccal cavity. In opening the mouth care must be taken, if spasm exists, not to break or displace loose teeth, especially when using Heister's mouth-opener. As

a rule the finger inserted behind the teeth will force open the jaws sufficiently for the insertion of a wedge or gag.* In the stage of excitement the chloroform should be pushed, provided respiration is unimpeded and regular, but if the respiration is impaired, the anæsthetic must be withheld altogether until breathing is again normal. Excitement passing off, rigidity of the muscles may persist for a time, even though the loss of lid reflex and fixation of the eyeball with a contracted pupil evidence the passage into the true anæsthetic condition (third degree of narcosis). This muscular rigidity eventually disappears ; some muscles, however, *e.g.* the recti abdominis, often remain rigid for a considerable time, especially if any excessive limitation of air has been allowed during the induction. Although unduly strong vapours cause spasm, a too feeble vapour unnecessarily delays anæsthesia and exerts a deleterious effect upon the heart.

The breathing is now regular, sometimes a soft snoring is heard, but no noisy stertor should exist. The presence of this is evidence of obstructed breathing, and its cause must be sought and removed. The administrator should notice whether expiration is fully performed and whether there is any duskiness about the face or ears. **Cyanosis, however slight, is to be avoided ;** it is caused by excessive quantities of chloroform and failing respiration. As soon as the patient is anæsthetic (third degree) the amount of chloroform must be lessened and only so much be given as is required to maintain complete anæsthesia. It must be remembered that until a patient has been in the state of complete anæsthesia for some time he is very prone to " come out " of the state rapidly, if either too weak a vapour is given him or, if some strong peripheral nerve stimulation is brought about by the operative measures in progress. To permit an operation to be commenced before full anæsthesia has been established is to court danger. Young children often appear to have passed into this degree of narcosis when merely asleep, but if the progress of the case has been carefully observed, no mistake need be made. A watch kept, on the respiration, the colour of the patient, and the condition of the **pupils** and **eye-**

* When any anoxæmia co-exists, with spasmodic closure of the teeth, it is usually possible to introduce a catheter through a gap between teeth and force oxygen in through the catheter by connecting it with a tube from an oxygen cylinder.

balls will enable the administrator to keep his patient anæsthetic, without deepening the degree of narcosis.* During the induction the eyeballs move ; the pupils react to light and gradually dilate. During the stage of excitement the dilatation becomes more marked. In the degree of true anæsthesia the eyeballs are fixed, and the pupils gradually contract, but remain sensitive to light ; the lid reflex disappears. In the fourth degree the eyeballs are rigidly fixed, slightly rotated upwards, the pupils dilate and are insensitive to light. This dilatation reaches its acme as death occurs in the fifth degree of narcosis.

The early signs of **returning consciousness** are, moving eyeballs with dilating pupils, return of the lid reflex, active reflex to light, and, if vomiting is about to occur, the patient swallows, grows pale, and his respiration becomes weak. On the other hand, the signs of **deepening narcosis** are duskiness or pallor, dilating pupils with fixed eyeballs, complete loss of the " light " reflex, flaccidity of the muscles, weakened respiration, and a soft, feeble, almost imperceptible, pulse.

The pulse, although a valuable sign of the *general condition* of the patient, is no guide by itself to the degree of narcosis. In cases in which much shock and hæmorrhage are present, the narcosis will rapidly deepen, even although no increased supply of chloroform is being given. This arises from the fact that the nervous system when drained of blood is more readily narcotised.

The degree of narcosis must be deepened or the reverse, according to the strength of the patient and the nature of the operation. When the patient is not made completely anæsthetic or the degree of narcosis is inadequate to the nature of the operation, so that the patient rapidly becomes no longer anæsthetic owing to painful sensory stimulation, dangerous conditions arise. When a patient is very lightly under chloroform there is always

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* The late Mr. Rutherford of Cambridge (*Brit. Med. Jour.*, June 21, 1913) contends that the lacrimal gland offers reliable information as to the depths of narcosis. As he mentions four " stages," it is difficult to be sure of the periods of narcosis to which he refers. In the " preliminary stage " the effect varies with the local irritation ; in the " excitement stage " secretion is active, tears form a pool at the inner canthus ; during the " stage of surgical anæsthesia " the lacrimal glands cease to secrete usually " before the complete abolition of corneal [*sic*] reflex." In the " stage of overdosage " no lacrimation occurs. It is doubtful, I think, whether these conclusions have as universal an application as Mr. Rutherford affirms. His observations are, however, interesting.

a risk lest the administrator should keep up a see-saw between excessively slight and unduly deep narcosis. Irregular breathing, and a tendency to strain, cough, or vomit, commonly appear under these circumstances, and the anæsthetist is tempted to put an end to such inconveniences by suddenly giving a greatly increased strength of chloroform vapour. This, under such circumstances, is tolerably certain to lead to overdosage and danger. A full and continuous anæsthesia should be aimed at, and to effect this it must be borne in mind that the intake of the anæsthetic should be equal to the amount exhaled by the patient. Assuming the supply of chloroform vapour is abundant, it has been proved that during the early part of the induction more chloroform enters than is expelled by expiration. In true anæsthesia about the same amount enters as is given off, and so soon as the percentage strength is lessened the quantity expired will exceed that inspired. This should occur steadily as the anæsthesia is maintained, since very much less chloroform, or rather a much lower percentage strength of chloroform vapour, is needed to prolong anæsthesia than is necessary to establish it. This is true provided respiration is not interfered with ; if obstruction occurs, less chloroform may leave the lungs and the drug will remain active in the cells of the tissues. While undue haste is always dangerous, excessive slowness in the induction of chloroform narcosis is also undesirable, and there is a proneness to sickness, and with it a fall of blood-pressure, which often induce extreme depression, or syncope, and it is believed, may predispose to the production of ventricular fibrillation. The time occupied in the induction varies considerably. The peculiarities of the patient, and the method delay or hasten the onset of anæsthesia. Five to ten or even fifteen minutes may be required to anæsthetise a patient. Besides the loss of conjunctival reflex, it is wise to wait for regular, easy breathing, a good colour, and a relaxation of the muscles before the operation is commenced. In abdominal operations this is extremely important, and an extra few minutes are well spent in obtaining such a result. If the induction is hurried and anæsthesia barely obtained, the commencement of the operation will cause the patient to pass back rapidly into lighter narcosis, the breath will be held, and the respiration become irregular. It will be extremely difficult if this has occurred to obtain subsequently a satisfactory anæsthesia throughout the operation.

It is very important to appreciate the fact that light narcosis, *i.e.* below the third degree, is undesirable, if not dangerous, at the period at which an operation is commenced ; yet when a patient has once been taken through the third degree, and has been truly anæsthetic for some time, he may often safely and satisfactorily pass back into the second degree during the subsequent conduct of the operation.

Recovery from the Effects of Chloroform.

Of persons who pass easily under chloroform, and who have taken only a small quantity, the recovery is marked by few noticeable symptoms. They awake as from sleep, are sometimes sick, or feel slight nausea, rarely complain of the persistence of the taste or smell of the vapour, and are prone to sleep. Snow states that persons become conscious in ten minutes after ceasing to inhale. When chloroform is carefully given by a dosimetric system it is quite usual for patients to resume consciousness within a few minutes of being returned to bed. They then usually go to sleep again and may sleep for an hour or so. If morphine has been given before the anæsthetic unconsciousness persists for a longer time, it may be for four or six hours. Old people are slowest to awaken. Syncope is a grave danger to all after severe operations associated with shock or loss of blood. It is most common in the case of the weakly, and is due to ischæmia in the cerebral circulation and fall of blood-pressure. Suddenly sitting up, as in the act of vomiting, even the lifting the patient, may cause faintness. Numerous deaths have been reported after chloroform inhalation due to the patient having been put back to bed and left unwatched. The patient in these cases has been suffocated either from malposition of the head, or through vomiting having taken place and the vomitus aspirated into the air-passages.

Difficulties arising During the Induction of Chloroform Anæsthesia.

Nervous persons and young children commonly **hold their breath**, or breathe so softly that they inhale insufficient vapour to establish anæsthesia within a reasonable time. This is usually the result of commencing the inhalation with too strong

a vapour. If the anæsthetic is withheld for a few respirations, the patient will resume his usual breathing and the chloroform can be given again, only more gradually. Breath-holding in the semi-unconscious state arises reflexly and from the cause mentioned above, and may be remedied in a like manner. The **screaming** of children needs care lest the deep breaths taken lead to an excessive amount of chloroform being inhaled. The anæsthetic should be given slowly until the child has stopped its cries.

Men with a powerful physique while in the second degree sometimes hold their breath and struggle, repeating the process at each attempt to give them chloroform. This condition is obviously dangerous, as any attempt to push the anæsthetic may lead to disaster. It can be overcome by changing the anæsthetic to ether, giving it freely for a few respirations either by means of an inhaler or an open mask. All air is excluded, the patient is held, and few compressions of the thorax are made with one hand. As soon as respiration is well started, chloroform can be substituted for the ether. **Struggling,** especially quite at the beginning of the administration, although frequently due to too strong a vapour, may arise from other causes not associated with overdosage. In the highly nervous, the neurotic, and especially in the alcoholic, the condition is common and pronounced. Unless the administration is being conducted by an accurate apparatus, which enables the chloroformist to lessen the percentage of vapour, the chloroform must be at once withdrawn until the breathing has resumed a regular rhythm. It is then to be given again, but more sparingly. **Breathing** may grow more and more **shallow, pallor** may appear, due to interference with the circulation. This alarming association of symptoms is not infrequently seen in children and feeble subjects. Its cause may be some slight interference with the breathing, such as sucking back of the tongue, falling of the jaw, mucus collecting about the laryngeal aperture, or through epistaxis, and the cause of this condition must be carefully sought for, and when discovered remedied.

The dangers of struggling when chloroform is being inhaled are due to fixation of the muscles of respiration and irregular breathing. The patient holds his breath, the diaphragm and chest are rigidly fixed, and this impedes respiration as well as circulation. He then suddenly takes deep breaths which,

if the chloroform mask has not been removed, will flood his lungs with a strong vapour and an **overdose** is taken. It is the concentration of this vapour, not its actual amount, which is deleterious. **Semi-asphyxia** provokes further struggling, and this leads to the entrance of more of the high percentage vapour into the lungs until the nerve centres, which are rendered more vulnerable by being deprived of oxygenated blood, are poisoned beyond recovery. Hence the absolute rule that **any interference with respiration calls for withholding chloroform** unless it is being given by a dosimetric inhaler and its concentration is not above 1 per cent.

The lips are often tightly closed over the teeth clenched by tonic contraction of the jaw muscles. If the tongue is caught between the teeth it will be badly bitten. To prevent this some anæsthetists place a dental prop between the teeth before starting the inhalation. Weakening of respiration and pallor in asthenic and especially in anæmic patients are usually due to a feeble state of the heart. If the head is placed at a lower level than the trunk, the symptoms of faintness will disappear and the induction will pursue a normal course. Retching and even vomiting may occur as a patient **begins** to inhale. When it is known that there is no food in the stomach, and that no condition exists which might lead to regurgitation of intestinal contents—as in cases of intestinal obstruction—increasing the supply of chloroform and pushing forward the lower jaw rhythmically will usually succeed in preventing vomiting. Nervous persons are liable to this inclination to vomit, and it is often the accompaniment of faintness. However, if food or intestinal contents are vomited, in spite of all precautions, the chloroform should be withdrawn, the patient's head kept low and turned to one side. Care must be taken by swabbing out the mouth to prevent aspiration of the vomit into the air-passages. It is best before recommencing the chloroform to have the stomach washed out. This, however, is seldom necessary in the case of young children. When once anæsthetised, the patient should not be moved or shaken, nor must he be exposed to draughts or any conditions which will chill his body.

Irregular breathing is a symptom to be carefully noted and corrected. It may arise from too rapid an induction by too strong a vapour, in which case more air must be given; or it may follow from too shallow a type of breathing, and a " see-saw "

method of giving the anæsthetic, such as by pouring a drachm of chloroform on the mask and letting it evaporate. Systematic dropping of the anæsthetic on the mask will correct this. Irregular breathing in light narcosis may herald faintness or vomiting, or the more serious condition of ventricular fibrillation mentioned above.

The operation should never be commenced until the respirations are regular and there is sufficient lung ventilation and the ocular signs indicate that the patient is in the third degree of narcosis.

Epileptics commonly have a fit during the induction of anæsthesia, and this alters the respiration materially. Provided the patient's tongue is protected from being bitten, the fit is no indication for withholding chloroform except at the time during which the breath is held.

Young **children** are very prone to **irregular sighing breathing,** especially if they have cried and struggled in going under the anæsthetic. The breaths are grouped, getting gradually weaker, then comes a pause followed by a long-drawn deep sighing breath, and this may very readily lead to overdosage. It is best to lower the head and stimulate breathing by rubbing the lips, lifting the jaw, or by giving a little ether on an open mask.

An extremely important point to bear in mind is that, although the loss of conjunctival reflex is regarded as the criterion of true anæsthesia, yet many operations may require a more profound narcosis than exists at the time this reflex disappears. Undoubtedly excessive deepening of narcosis in all cases is fraught with danger, and the administrator who has to bring this about must be sensible of the risk and watch with the utmost care for the signs of it. The relaxation of the recti abdomidis muscles in strong athletic adults, and the slow shallow breathing, which are commonly considered necessary for the proper performance of the abdominal operations, can only be obtained by increasing the dose of chloroform until the medullary centres are brought in some degree under the influence of the anæsthetic. When this degree of narcosis is present even a slight interference with respiration, or the occurrence of hæmorrhage, may lead to enfeeblement of or even to cessation of breathing. The blood-pressure will under these circumstances become markedly lowered, thus lessening the flow of blood through the cerebral circulation,

Persons of different **physique** require different amounts of
chloroform, and the requirements of operations also call for
a like variety in the depth of narcosis. It will be found that
these variations in dosage are especially needed during the period
of induction, but may be called for also in the later phases of the
administration. Thus the feeble and those who are profoundly
shocked will need very litttle anæsthetic to maintain anæsthesia ;
the vigorous and alcoholic will require a large amount to keep
them relaxed and abolish all reflex movement. Since the severity
of the after-effects is directly due to the amount of the anæsthetic
which has to be eliminated, it is necessary to limit the quantity
given as much as the exigencies of the operation and those of the
individual will permit. It must be clearly understood that a
depth of anæsthesia adequate for each patient and each type
of operation is always essential, since incomplete and even too
light a grade of anæsthesia are fraught with danger. The
anæsthetist must be guided by the respiration : if it is obviously
free and unhampered the patient's condition is satisfactory,
if it shows signs of irregularity or of weakening the patient is
having too much of the anæsthetic, assuming, that is, that no
physical cause is present which interferes with breathing.

As to the incidence of **danger,** it may be stated that the strong
and athletic are, if anything, more liable to accident than are
the feeble. No age or temperament is free from possible peril,
nor can it be accepted as truth that a person who has many
times taken chloroform with impunity therefore enjoys an
immunity from its risks. Chloroform, like any other drug, pro-
duces effects corresponding to dosage, and there is little doubt
that for most persons the dose is determined by the resistive
powers of their tissues and to a lesser degree by their body weight
and physique. It is possible, nay even probable, that the re-
sistance evinced by some patients is peculiar to themselves.   Just
as minute doses of potassium iodide, or other drugs, will cause
great inconvenience to certain people, so even small amounts of
chloroform will produce much greater physiological effects upon
some persons than upon others. It is this which renders it
necessary to commence the administration of chloroform with
caution, and to augment the dose only when it has been ascer-
tained how the patient reacts under the influence of the drug. Nor
can it be too strongly urged that only by constant observation of
the phenomena of anæsthesia and a right interpretation of their

significance will safety and success be ensured. The guides are first and foremost **respiration,** which must be studied, not only by watching the thoracic movements, but also by noting the force of expiration. This is best done by placing the hand from time to time over the patient's mouth. The colour of the face, lips, and ears will give a fair indication of the state of the blood— *i.e.* whether it is being properly oxygenated—while a finger occasionally placed on the pulse will gauge the blood-pressure ; and, lastly, the ocular phenomena will indicate the depth of narcosis. In the early degrees of narcosis the conjunctival reflex is brisk, the pupils are moderately dilated, and the eyeballs move more or less slowly. In the third degree—the stage of true anæsthesia—the conjunctival reflex is abolished, the eyeballs cease to move, and the pupils contract and may be reduced to a pin's point. Deeper narcosis, when the patient is entering the fourth degree and the medullary centres are becoming overdosed, is revealed by gradual failure of respiration, most marked by the feebleness of expiration, by dilatation of the pupils and lessening or loss of the light reflex. Ocular phenomena are of less value as a guide in the case of children. It should be remembered that the conjunctival reflex disappears before the corneal reflex, and that the latter therefore signifies a profounder state of narcosis and one which is very near the zone of danger. As will be evident from a study of this and the following sections, many if not most of the difficulties and complications connected with chloroform inhalation arise during the period of induction. Such dangers may be due to overdosage or to under-dosage ; indeed, some authorities regard the second as the most common cause of death in this stage. Still, I think there are very many cases of deaths occurring during induction which are in fact the result of interference with respiration by causes within or external to the patient. If inadequacy of the strength of chloroform vapour presented to the patient kills some through ventricular fibrillation, there are many, and I think more, persons killed by inadequate lung ventilation or intercurrent asphyxial conditions. Anoxæmia is a potent agent for danger under chloroform, and must claim the anæsthetist's untiring watchfulness in order to detect it and adopt the suitable remedial measures. We may consider in this place whether there are any special methods the adoption of which will obviate such dangers, and further whether in particular types of persons the pursuing of

such measures may not remove the dangers, and lessen the
difficulties especially associated with such types.

What is the position of chloroform as regards its safety ?

The formidable list of deaths and dangers which must be
present in the mind of the student of anæsthetics is apt to pro-
duce an undue feeling of timidity in handling this anæsthetic.
There is no doubt that chloroform is dangerous when given by a
tyro and by a method which leaves the strength of the vapour
employed rather to chance than to knowledge ; and when through
timidity or other cause an intermittent or inadequate supply of
the anæsthetic is relied upon.   When once the lesson is learned
that due dilution of its vapour lessens its dangers, and that this
is best done by some scientific method ensuring definite percen-
tages so that a maximum strength at or below 2 per cent. is
ensured, the anæsthetist soon recognises how safe chloroform
administration can be made. As Waller has pointed out, the
essential training of a chloroformist consists in his making him-
self master of the phenomena associated with any given per-
centage strength of chloroform vapour. This accomplished,
he will rarely allow his patient to get a vapour strength above
2 per cent. whatever method he pursues, and if he does so it
will be of set purpose and with a keen appreciation of the fact
that he is encroaching upon the danger zone. Such a training
is best obtained by familiarity with some dosimetric apparatus,
as this will enable the learner to study the wide range of difference
which exists among individuals as regards the way they react
towards this anæsthetic.   Thus, if a 2 per cent. is a safe maximum
for an ordinary person, the patient whose respiration is hampered
will require less.   While the maximum is needed for induction,
persistence in its use when the operation has been in progress for
some time will lead to an excessive depth of narcosis.   The
danger of open methods is that they tend to establish stereo-
typed systems of dosage, because it is more difficult to lessen the
amount given, and they also tend to hasty and ill-judged in-
crease of dosage at moments of stress when the surgeon calls for
a deeper narcosis.   Although the experienced man may be proof
against such imperfections in the methods, the beginner is not ;
and can only become so when he has learned to estimate the exact
effects of definite dosage with chloroform.   ·

The experience gained in war surgery during the past few years
has demonstrated that under some psychological stresses the

2 per cent. limit may in a certain number of cases fail to induce true anæsthesia within a reasonable time. This, however, does not invalidate the general principle that the 2 per cent. maximum is a safe one upon which to work, although passing beyond it may at times be necessary. The operations of to-day involve such tremendous trauma, trenching as they often do upon the very arcana of life, that a profound narcosis is often rightly insisted upon by the surgeon to obviate the dangers of after-shock and to facilitate his manipulative measures.

VARIOUS METHODS OF GIVING CHLOROFORM.

1. Antecedent employment of alkaloids.

2. Antecedent use of other anæsthetics, *e.g.* nitrous oxide followed by ether.

3. Ethyl chloride in sequence with ether, followed by chloroform.

4. Combinations of alcohol and chloroform.

5. Combinations of ether and chloroform with or without alcohol.

6. Methods combining two or more of these methods and the routine employment of oxygen.

7. Intratracheal insufflation.*

All these **sequences** are discussed in a later chapter, so that it is only necessary to point out that when alkaloids are employed the induction of anæsthesia is more tranquil, and therefore is probably more safe ; less of the general anæsthetic is required —thus the after-effects are diminished.

The object of employing such sequences is to shorten the induction period and to give a safer anæsthetic at the time when struggling is most liable to occur.

When a patient has had a spinal anæsthesia established and its effect has passed off before the operation has been completed, the anæsthetist may be called upon to administer chloroform. In doing this he should bear in mind that the patient has probably taken food, or in some cases alcohol, shortly before the injection

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* This method has been recently introduced, and if the first favourable impressions of it are confirmed when we have a wider experience of its employment, it may become a routine method in certain cases. It is described in Chapter VIII.

into the theca was made, and so will be prone to vomit while inhaling chloroform. Chloroform or other anæsthetic is now commonly given throughout the whole operation to patients who are also made subject to spinal anæsthesia, and the new conditions thus brought about require close study.

The Use of Chloroform in the Case of Special Types of Patients.

1. Children and the aged.
2. Extreme asthenia.
3. Athletic persons.
4. Alcoholic persons and those addicted to drugs.
5. Persons suffering from pre-existing asphyxial conditions (anoxæmia).
6. General diseases of respiration, circulation, and the nervous system.
7. Toxæmia.
8. Pyrexia.

1. Chloroform in the extremes of life—**infants** and **young children.** The dictum that children are less liable to accidents under this anæsthetic than are adults must be dismissed as untrue. The very young are peculiarly liable to danger during the induction period, and to grave after-effects (post-chloroform toxæmia—acidosis), so that especial care is essential in their case to avoid overdosage. Open methods so commonly employed are especially apt to lead to this, since children are usually terrified, often hold their breath and gasp, their respiration shows alternations of breath-holding and violent and deep inspirations, making induction both difficult and dangerous. Further, children often go to sleep under chloroform, and in this state respiration is so shallow that, unless the little patient is roused and breathing made deeper, he will take a very long time to be rendered truly anæsthetic. It is often extremely difficult to decide whether a child is asleep or " under," the phenomena are practically the same, so that some pain-giving stimulus must be applied before the operation is commenced. The apparent tolerance of large quantities of chloroform is really illusory, the fact being that owing to poor lung ventilation very little of the chloroform vapour is actually inspired. Dosimetric methods

are certainly the best for children, although, owing to the diffi-
culty of obtaining an accurately fitting mask for a small child,
such methods are not easily applied. With delicate children,
it is best to have the head lower than the trunk, and, if breath-
holding and struggling occur, to replace the chloroform by ether
given by a dropping method until the child has become uncon-
scious. The pungent vapour rouses the patient and his struggles
induce deep breathing, which is an advantage with the last-named
anæsthetic. A few drops of eau de Cologne or oil of bitter orange
dropped with the chloroform disguises the smell of the latter, and
will often induce the timid child to breathe easily and willingly.
No pallor or asphyxial complications should go unrelieved, as
serious danger comes rapidly in the case of children. Depression
of the head will relieve the one, and hooking forward the man-
dible with a finger in the mouth will remove the other, especially
if the child's chest is compressed with the hand. The chloroform
must be withheld while these steps are taken.

Children who have struggled and breathed in an irregular
fashion during the induction commonly develop a curious type of ·
respiration. The breaths are grouped as in Cheyne-Stokes
breathing ; then follows a deep sobbing inspiration which is
succeeded by an apnœic pause. This condition is one of danger
and is usually associated with pallor and blueness of the lips.
The anæsthetic must be withdrawn and oxygen given, while
respiration is encouraged by chest compression and rubbing the
lips with a soft handkerchief. If chloroform is persisted in at
all, it must be given very sparingly and much diluted, but as a
rule little if any more anæsthetic will be required for some
minutes. Under no circumstances should the inhaler be
reapplied until the respiration has become more satisfactory
and regular.

Simulating the condition just described as due to overdose
and fall of blood-pressure, is one which arises from quite another
cause, viz. too light a narcosis. The pallor in this latter state is
premonitory of the act of vomiting. It is unwise to attempt
to check this in the case of delicate children, since vomiting
is always associated with a fall of blood-pressure which is often
considerable. When retching has ceased, the anæsthetic should
be reapplied, the head being lowered and complete narcosis of
the third degree—anæsthesia—established. I prefer to do this
by using a little ether, in spite of the fact that that anæsthetic

usually makes children very sick. The effects of cold and of shock and of prolonged fasting tell rapidly upon children, and must be counteracted, or chloroform, given in even small quantities, will depress these patients to a dangerous degree. Children under chloroform, if lifted at all, must be carried with the utmost care to avoid the head being raised or the body jolted. The dangers of giving chloroform to children the subjects of **status lymphaticus** are considered later on.

2. In the case of extreme **asthenia** the danger of undue fall of blood-pressure is to be kept in mind, and avoided by keeping the strength of the vapour low. Such patients really require very little of any anæsthetic and cannot take an ordinary strength of vapour without risk, but it is essential that they should be made fully anæsthetic since they are peculiarly liable to nerve storms associated with circulatory failure. If respiration is poor and the lips are bluish, oxygen should be given very freely.

3 and 4. **Athletes, muscular persons** and **alcoholics** are peculiarly apt to struggle in the initial stages of the induction period, and later there is usually marked muscular spasm which may seriously prejudice respiration. These conditions are often, if not always, the outcome of some asphyxial state due to breath-holding, excessive strength of the vapour inhaled, or sucking back of the tongue. Any such cause must be sought for and remedied. It is dangerous to attempt to overcome muscular spasm by recklessly pushing the anæsthetic ; indeed, unless the chloroform is being given by a dosimetric method, which is the safest for patients of such types, the anæsthetic should be withdrawn until the complication has passed off. As mentioned above, chloroform is a bad anæsthetic for such types of people, and induction should, whenever it is possible, be obtained by the gas and ether sequence followed, if this be essential, by chloroform.

The **habitual use** of **hypnotics** renders patients difficult to anæsthetise. They take a large quantity of chloroform and are apt to pass into a drowsy condition in which the respiration is shallow, so that they actually get little of the anæsthetic into their lungs. The knowledge of this fact will provide a clue to the remedy, viz. constant attention to the breathing and stimulation by lip rubbing, jaw traction, and so on. When anæsthesia has been once established the amount of chloroform given must be lessened, as such patients remain deeply anæsthetised for a long time after the anæsthetic has been withdrawn. It is

well in all cases to ascertain whether a patient has been given powerful sedatives for some period before the operation, or indeed, on the night before it is performed.

5. Pre-existing **cyanosis** due to some cause which impedes respiration requires the use of oxygen and high dilution of the chloroform, and the removal of the *causa causans* if that be possible, *e.g.* correction of a faulty posture. If the cyanosis depends upon a condition the effects of which may become accentuated under narcosis, this fact must be borne in mind and precautions adopted. The interference with respiration due to lesions of or pressure upon the spinal cord is best treated by inducing anæsthesia by the use of a Vernon Harcourt regulator and a free supply of oxygen. When full anæsthesia is obtained, practically no more anæsthetic will be needed until the close of the operation, when the skin sutures are introduced. The head should be kept rather high in the case of such patients. Respiratory failure is peculiarly liable to occur during operations upon the spinal cord, especially if a deep narcosis has been incautiously allowed to arise. After the initial incisions the patient should be in the second degree of narcosis.

6. No general rules can be formulated for these cases since each must be treated with the view of combating the dominating dangers incident to the particular disease. **Respiratory difficulty** calls for careful attention to posture, limitation of the strength of the vapour in use, and sedulous avoidance of " crowding on " of the anæsthetic. Oxygen is of great assistance. Perhaps the main fact to be emphasised is that throughout the giving of chloroform to such patients, the attention should never be allowed to flag from watching the breathing. The slightest lessening of its amplitude, if associated with pallor and returning activity of the conjunctival reflex, usually means the narcosis is too light and more anæsthetic is needed. It is, however, necessary to ensure full respiration while this is being done, or the blood-pressure will fall and danger ensue. Pulling forward the tongue and pressure on the chest are commonly successful in restoring normal respiration. If, however, respiration grows shallow and irregular, and associated with this are cyanosis, pulselessness with some dilatation of the pupils, the ocular globes being fixed, and there is also loss of the conjunctival reflex, the patient has taken what to him is an overdose. The anæsthetic must be withdrawn, oxygen given, and respiration restored

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by the usual means. **Circulatory failure** again may be the dominating danger, and if this is recognised the anæsthetist will have the key of the situation, for he will know that a low blood-pressure is only consistent with an amount of the anæsthetic which under normal conditions would be inadequate. Posture also in these cases is important so that the nerve centres may not be unduly depleted of blood. **Diseases of the nervous system** become important in the present connexion in so far as the lesions interfere with the due nerve control of respiration and circulation. Such interference has already been considered. The tremors of **paralysis agitans** disappear under anæsthesia. When **bulbar paresis** exists the utmost care must be taken to maintain the patency of the air-passages and strict limitation of chloroform practised. Any asphyxial complication is peculiarly dangerous in these patients. Diseases in which the **quantity** and **quality** of the **blood** are affected are, I think, especially dangerous, because we possess abundant evidence to show that the tissues of the body are more easily affected and damaged by even small quantities of chloroform, and are liable to suffer from oxygen deprivation, when the blood-supply is inadequate or its quality is poor.

7. Germane to these considerations is the question of **toxæmia**, and with this we may include that curious congeries of symptoms called **lymphatism** or **status lymphaticus**. So far as we know, those who at death reveal the lesions of hyperplasia of the lymphatic structures, a depraved blood condition, and often imperfectly developed heart and blood-vessels, show no well-marked clinical signs of their state which differentiate them from delicate children and " overgrown " adolescents. Whether they, like cretins and others, are in fact poisoned by an auto-toxæmia cannot be discussed in this place. It will be sufficient to say that in all toxæmic states such as cholæmia, uræmia, cancer, diabetes, septicæmia, and lymphatism, the resistance of the tissues towards chloroform is lowered. To put it another way, if in normal persons a given quantity and vapour strength of chloroform are safe and will produce anæsthesia without causing dangerous symptoms, that amount will in the case of all persons who suffer from toxæmia prove dangerous and even lethal. The problem which must be solved for each individual patient is to discover, by careful adjustment of the anæsthetic, how far it is safe to push it. It will be found that very little is

really required to induce unconsciousness and still less to maintain it.

8. The condition of **pyrexia** again falls almost into the category of cases classed under toxæmia, and its treatment from the point of view of the anæsthetist is that already enunciated. It may, however, be added that the heart factor is an important one in pyrexia, and its dangers are in most cases connected with cardiac failure.

Complications arising during the administration of chloroform and their treatment :—

General minor complications.— A word may be said about posture. The arms must be placed so that there is no possibility of pressure being exerted upon nerve-trunks, as this may cause peripheral palsy. The face and eyes must be guarded against chloroform dropping upon the skin or conjunctiva. Vaseline over the point of the chin, the nose and the cheeks, and castor-oil dropped in the eyes will prevent this danger. When dropping the anæsthetic from a bottle care is necessary that the last drop does not fall outside the mask and on to the face or neck. If the patient is a child its heels should be held, or be put on a pillow, as an infant is liable to bruise them if it kicks, or, as is common, drums on the table with its heels. High-bridged noses of the " Roman " type should be protected or the pressure of a mask or face-piece will leave them sore and painful for days. Urination and defecation may occur during the induction and need proper attention. When the lithotomy position is used the thighs must not be forced back too much on the abdomen, as in stout persons respiration may be interfered with in such a position, while neuritis and palsy or even rupture of the popliteal artery have been caused by careless fitting of the Clover's crutch. The strap of the crutch must be placed over one shoulder and under the opposite one, and the face turned to the latter side.

INTERFERENCE WITH RESPIRATION.

This may arise from MECHANICAL CAUSES, or result from the direct action of chloroform upon the RESPIRATORY MECHANISM (overdose). Further, if the circulation becomes very feeble the medullary centres may be inadequately supplied with blood and respiration fail.

The symptoms evoked will depend upon the extent to which the patient's breathing has become hampered, and the treatment will vary according to the cause.

1. **Mechanical.**—The falling together of the arytæno-epiglottidean folds occludes the larynx, and interferes with inspiration. It is an extremely common accident, and if not observed and remedied may become very serious. The patient's breathing becomes irregular and harshly stertorous, the chest movements are not stopped but their amplitude is lessened, the face grows dusky, and this is seen especially in the ears and lips. Respiration then ceases, and the patient's face becomes black. Inflammatory or other swellings pressing upon the trachea or lessening the patency of the upper air-passages, binding down of the tongue or neck by old scar tissue, engorgement of the tongue, tonsils, and adjacent structures, may interfere with respiration. These conditions, however, do not always give rise to symptoms until the patient is partly under chloroform or until struggling or breath-holding has produced some asphyxial condition. When this last occurs the symptoms rapidly develop and respiration becomes seriously hampered.

The tongue may fall back and so occlude the laryngeal opening. This is perhaps the commonest accident. When the patient is deeply under the anæsthetic the lower jaw and with it the hyoid bone drops, and the tongue is carried back so as to close the larynx. The air is thus prevented from entering the lungs, as every inspiratory effort only sucks the epiglottis back. It thus acts as a valve permitting some expiration, but no inlet of air. The movements of the chest still persist, although practically no air is entering. As asphyxia is developed the respiratory movements become irregular, and finally cease. Usually, but not always, snoring stertor is present under these circumstances. The signs of asphyxia are soon seen, the face becoming dusky, then blue, and finally a mottled black ; the pulse weakens ; and, unless promptly relieved, the patient dies.

Mucus, or **blood-clot,** or other fluid such as **vomitus,** may sometimes collect over the upper opening of the larynx, and in persons whose respiratory efforts are not vigorous may cause suffocation. Insufficient air exchange leads to signs of asphyxia more or less pronounced, the most striking of which is the progressive duskiness of the patient's face. In this case the pharynx should be sponged out and the chin jerked up, a manœuvre often

sufficient to dislodge the obstruction and restore normal respiration.

The posture requisite in various operations hampers breathing, and if the patient is profoundly under chloroform it often leads to interference with breathing. Such positions are : the extreme " lithotomy," when the thighs are flexed strongly upon the abdomen and the buttocks supported on a sandbag ; an extreme Trendelenburg, when the intestines and abdominal contents press upon the diaphragm, limiting its excursion—this is made worse if the arms have been brought up and fastened above the head, thus in part fixing the thorax ; the " semi-prone " and, worse, the " prone," adopted in some kidney and rectal operations ; the lateral decubitus in cases where an empyema or extensive pleural effusion is present. It is absolutely essential, if chloroform is used at all for these patients, that the anæsthetic should be given gradually, so as to avoid too great a limitation of air. After full anæsthesia has been obtained the patient should be allowed to pass back into the second degree of narcosis with a fairly brisk conjunctival reflex. Any progressive cyanosis is a definite warning that the posture must be altered and the patient's breathing restored to its normal amplitude.

Entrance of foreign bodies into the larynx or trachea.—Teeth, natural or artificial, pieces of bone, blood-clot, pus, vomit, nasal polypi, masses of new growth, or of dental tartar, gags, sponges, gauze mops, may drop back and enter the air-passages, or, in the case of solids, may become jammed in the œsophagus, and so provoke asphyxia by mechanical pressure upon the larynx. Small or soft substances which enter the larynx may set up spasm and so prevent passage of air, or they may pass into the trachea or bronchi, and produce urgent dyspnœa and suffocation. So long as the coughing reflex persists foreign bodies will not, as a rule, pass the vocal cords, but in deep narcosis this safeguard no longer exists. It is, therefore, better to employ light but adequate narcosis in operations upon the buccal cavity and upper air-passages in order to avoid this danger of suffocation through foreign substances or liquids entering the lungs.

Treatment.—The falling together of the arytæno-epiglottidean folds and falling back of the tongue are less liable to occur if the head is placed on the side, so that the weight of the tongue does not tend to drag it backwards. Every precaution should

be taken to avoid the danger of foreign bodies being aspirated into the air-passages. If a post-pharyngeal or tonsillar abscess has to be opened, the pus and blood must be sponged out of the mouth. All loose teeth, tartar, and masses of growth should be noted, and if possible removed or guarded. When the position of the head has been adjusted, and the other precautions mentioned have been taken, any interference with breathing or duskiness of colour will attract attention. If they occur the mouth must be opened. In some cases this is difficult, as the asphyxial condition causes spasm of the masseter muscles, and the jaws become firmly set. A gag or mouth-opener can sometimes be introduced in a gap between teeth, and failing this it may be necessary to force out a tooth in order to introduce the mouth-opener. When the mouth is opened the tongue should be grasped with forceps and pulled forcibly out, while any foreign body which is seen to have fallen back over the opening of the larynx is seized with forceps and removed. In the case of blood, mucus, vomit, or other liquid, sponging out the back of the pharynx will remove the cause of the dyspnœa. The tongue should be manipulated without roughness. If diseased, and force is suddenly applied, the tongue may be torn, and even if healthy its under-surface will be badly cut and lacerated unless care is taken to avoid its being stretched forcibly over the lower incisors. A pad of gauze or lint, or the corner of a towel, should be placed between the lower surface of the tongue and these teeth. In many persons the upper teeth articulate in front of their opponents, and pushing forward the lower teeth will fail to carry the tongue clear of the glottis. It is, however, only necessary in these circumstances to depress the lower teeth by opening the mouth, and then to carry them forward until they are in front of the upper incisors. When this is done the pushing forward of the lower jaw by the fingers applied behind the angles of the jaw will keep the air-passages open.

When suffocation is being caused by spasm of the larynx, due to the impaction of a foreign body, its relief must at once be obtained by performing tracheotomy, and by sucking out blood-clots, masses of growth, etc.*

* An instructive case occurred under my charge at University College Hospital. A man from whom the upper jaw had been removed by the late Mr. Christopher Heath was under operation for a recurrence of epitheliomatous growth, when his respiration suddenly became hampered, and

In many of these conditions, if respiration has actually ceased, it will be necessary to perform artificial respiration as soon as the cause of the obstruction to breathing has been discovered and removed.

Inversion is also of value in cases when it is feared that blood has entered the windpipe. After tracheotomy, sucking the tube is usefully supplemented by inversion.

Insufflation of the lungs by means of a catheter passed through the larynx has been recommended, but it would appear less effectual than tracheotomy and artificial respiration, aided, when need be, by sucking out blood or mucus from the tracheal opening. When a motor-driven insufflation apparatus is at hand it can be used with every hope of success. Catheterising a bronchus has, it is stated, saved a patient's life when other means had failed. If the foreign body has passed through the larynx and is lodged in a bronchus, it is best, unless asphyxia is imminent, to avoid a hurried tracheotomy. Subsequently a formal operation for the removal of the tooth, or whatever it may be, can be undertaken deliberately and with aseptic precautions, or the foreign body may be located by the aid of bronchoscopy and removed.

2. **Asphyxial** conditions occurring during the inhalation of chloroform, and due to other than mechanical causes, are of the greatest importance. While many authorities have contended that such complications do not constitute the only or primary dangers of chloroform, all admit their constant occurrence and extreme peril. Although, as Snow pointed out, actual deaths from failure of respiration without initial interference with circulation are few, yet accidents from interference with breathing are very common and prove fatal unless recognised, as they should be, and promptly dealt with. Further, resuscitative measures, unless very long delayed, should prove successful in most instances of respiratory failure under chloroform, provided that the blood-pressure has not fallen below a certain point and the protoplasm of the respiratory centre has not been destroyed by an excessive tension of chloroform in the blood.

When chloroform at the commencement of an inhalation is presented to the patient in too **concentrated** a vapour, **forced**

signs of impending suffocation appeared. Tracheotomy was promptly performed, the tube sucked, and several small masses of the growth withdrawn from the windpipe in this way. The man's breathing was restored, and the operation was completed.

holding of the **breath, struggling,** and even **spasm** of the **glottis,** may result. There are usually violent movements, the pupils are widely dilated, and the face wears an expression of terror, cyanosis rapidly deepens, and the respiration suddenly ceases. It may be sufficient to withdraw the anæsthetic and compress the chest with the hand, and when respiration is resumed to give it again more diluted and more guardedly. It should be adopted as a rule, that any of the symptoms cited demand the immediate withdrawal of the anæsthetic. If, in a deeper degree of narcosis, the vapour of chloroform is allowed to be stronger than can be safely breathed, that is 2 per cent., the amount absorbed into the blood gradually increases, and the patient passes into the fourth degree of narcosis (Snow), weakening of the respiration and duskiness of the skin and mucous membranes ensue, without any warning symptoms except the increasing enfeeblement of respiration. Finally, breathing stops. But this result may arise more suddenly when a patient, already deeply under the anæsthetic, is made to breathe a fresh and inadequately diluted supply of chloroform ; the medullary centres then become rapidly over-narcotised. These forms of respiratory failure are especially liable to occur in individuals suffering from pre-existing respiratory disabilities, *e.g.,* the anæmic, the cyanotic, the emphysematous. Persons who suffer from some condition which interferes with respiration are liable to have their breathing rendered still more difficult as they pass under the influence of chloroform. In cases of cerebellar tumour, spinal disease affecting the upper dorsal or cervical regions ; in cases of thoracic disease when one or both lungs are interfered with, such as hydrothorax, œdema of the lungs, or empyema thoracis ; and in cases of abdominal tumours when the upward pressure embarrasses breathing, a very small amount of chloroform may actually cause arrest of respiration. There is another type of patient who incurs a similar risk. The danger arises from obstruction in the upper part of the respiratory tract such as may arise from inflammatory swelling in the cellular structures of the neck, masses of glands, a goitre, œdema, or abscess pressing upon the trachea. As in the other class of cases to which reference is made above, very small quantities and low percentages of chloroform may prove fatal through interference with respiration. It should be borne in mind that in these cases a vicious circle soon establishes itself. The initial respiratory

difficulty leads under chloroform to venous congestion, and this in its turn causes still further interference with breathing.

Treatment.—If the respiration is closely watched and inspiration and expiration are seen to be natural, most of the dangers mentioned above will be avoided. Any deviation from the normal breathing should be observed and adopted as a guide as to whether more or less chloroform should be given.   When respiration becomes ineffectual or ceases, the chloroform apparatus must at once be taken from the patient's face, the head extended on the trunk, the tip of the tongue drawn *out of the mouth*, and artificial respiration practised.   If fluid is in the lungs the Marshall Hall plan should be adopted ; in other cases Sylvester's or Howard's method may be used.*   The movements must be made deliberately and accurately, and extreme care taken to perform them synchronously with any slight chest movement which Nature is able to make.   When the patient has a rigid thorax, compression of the abdomen with the view of emptying the lungs by forcing up the diaphragm is an aid to artificial respiration, and should not be neglected.   For young children and persons whose ribs are easily compressed, the lateral decubitus may be adopted.   The hands of the anæsthetist are then so placed as to grasp the upper side of the thorax.   Rapid compression and relaxation are then practised, and air is thus made to enter and leave the thorax.   In cases in which the arms cannot be used, as after amputation, mouth-to-mouth respiration may be adopted.   The nose must be closed during inspiration.

Professor Wood assures me that since he has adopted " forced respiration " he has never seen any fatalities under chloroform. Many apparatus for perflation of the lungs have been invented ; perhaps Fell's is one of the best.   A tube introduced into one nostril and connected with a powerful foot-bellows will easily fill the lungs.†   In cases of threatened death from respiratory paralysis I have perflated with oxygen in this manner, or directly through the larynx, and have restored some cases which appeared quite hopeless until I had adopted this measure.   Strychnine injected hypodermically (gr. $\frac{1}{60}$ to $\frac{1}{30}$) is usually held to be a valuable adjuvant, but is ineffectual unless artificial respiration is vigo-

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* In appropriate cases Schäfer's method should be adopted in preference to the others.   These methods are described in Chapter X.

    Great care must be used not to rupture the air-vesicles by undue vigour in perflating the lungs by means of the bellows.

rously kept up while the strychnine is absorbed. Hobday suggests
hydrocyanic acid as an antidote to chloroform, but the plan has
not been used upon human beings, and is probably not devoid
of danger. Whether strychnine given in such heroic doses as
those mentioned is of much value is an open question. I am
convinced that very large doses such as gr. $\frac{1}{10}$ introduce a fresh
danger and should be avoided. It is better to give smaller doses
repeatedly rather than one massive dose; however, strychnine
in chloroform poisoning is of doubtful value. Oil of camphor is
regarded by some as a safe and more valuable antidote in chloro-
form poisoning.

(See Chapter X., " Accidents of Anæsthesia.")

FAILURE OF CIRCULATION.

Syncope.—Failure of the heart may occur quite at the com-
mencement of the administration (primary cardiac syncope)—
that is, after two or three inspirations of chloroform vapour—or
it may supervene much later—in the third degree. In the early
degree of narcosis, syncope has been variously accounted for;
it has been attributed to reflex inhibition of the heart excited
by terror, or by the irritation by the chloroform vapour of the
sensory nerves of the pharyngo-laryngeal mucous membrane and
pulmonary tract; or to an individual susceptibility to chloroform
vaguely called the " chloroform idiosyncrasy." Cases have been
recorded of sudden death, provoked by fear, in persons about
to be operated upon, who have either taken no anæsthetic, or
have imagined, erroneously, they were being chloroformed, while
in reality they were inhaling eau de Cologne, or an equally in-
nocuous vapour. Persons may, and no doubt do, faint from
apprehension when about to take an anæsthetic. Many deaths
have occurred from this cause, so it must not be ignored when
considering the perils during anæsthesia, although the anæs-
thetic may have no direct causal relation to the fatality. It is
unquestionably highly important that all perturbing causes pro-
vocative of fear, such as loud and technical talking descriptive
of the steps of the operation, should be carefully avoided in the
patient's presence. No movement, such as uncovering the field
of operation, suggestive of the commencement of the operation,
should be permitted until unconsciousness is well established.
Fear and trepidation must always be met by kindly reassurance,

while haste and brusque handling should be studiously avoided. The commencement of the operation before complete anæsthesia has been induced is certainly liable to cause syncope by reflex inhibition of the heart.

The imperfectly chloroformed patient is furthermore prone to syncope. It seems probable that inhibition of the heart takes place as a result of stimulation caused by cutting the skin, especially over a sensitive area, and this stimulus is communicated along sensory nerves whose conduction is not abolished. Records of death in a state of incomplete anæsthesia show how often a fatality arises when even minor, although painful, operations, such as reduction of dislocated limbs, circumcisions, etc., are being performed. During incomplete anæsthesia, the heart is peculiarly liable to reflex inhibition, since the excitability of the vagi, as Embley has shown, is increased in the early degrees of narcosis, and so brings about a rapid fall of blood-pressure, which may prove fatal before the heart escapes from the vagal inhibition. Dr. Levy, however, regards death under incomplete anæsthesia as due to ventricular fibrillation, and he cautions against irregular and intermittent chloroformisation, since such faulty methods of administration cause cardiac irritability in light narcosis which may produce fibrillation.

Symptoms.—Extreme and ghastly pallor, with some blueness of the ears and finger-tips, wide sudden dilatation of the pupils, fluttering feeble pulse, and cessation of respiration and of all perceptible heart movements, usher in this syncope. There is little or no warning, nor can the most careful preliminary examination give an indication of cases in which this danger is likely to occur. Persons the subjects of fatty degeneration of the heart, of aortic or advanced mitral disease, are always liable to syncope, but the robust and vigorous incur a like risk, and are sometimes the victims of syncope occurring in the initial stage of taking chloroform. Syncope may occur in other degrees of chloroform narcosis (secondary cardiac syncope), but in these cases there is commonly more warning ; there is a gradual failing of the heart, evidenced by weakened and often intermittent pulse, pallor, cyanosis, cessation of hæmorrhage, and dilatation of the pupils, with failure of respiration. The cause of syncope if we exclude surgical shock, hæmorrhage, and sudden change in the posture of the patient's body, is either, ventricular fibrillation under incomplete anæsthesia (and this possibly

includes deaths in the status lymphaticus), or sudden or gradual poisoning of the patient by an excessive vapour strength of chloroform. I have never seen syncope occur when 2 per cent. vapour was being breathed, although I have seen some slight interference with circulation with this strength of chloroform. With percentages above 2 syncope is not so uncommon, and it is usually FATAL when STRONG VAPOURS are in use.

Treatment.—*Chloroform inhalation must be at once stopped*, the patient placed so that his head lies at a lower level than his abdomen, and when possible his legs should be raised, in order to assist the return of blood to the heart and brain. Complete inversion of the patient as practised by Nélaton is certainly the most important remedial measure we possess, but should never be employed when asphyxial complications coexist with the syncope. The respiration, which will have ceased coincidentally with the cessation of the heart's action, must be kept up by the artificial respiration methods of Howard and Sylvester (see Chapter X.). When syncope is presumably the result of over-distension of the right side of the heart, the blood being collected in the abdominal veins, inversion would, it is pointed out by Leonard Hill, have the effect of still further filling the right heart. He suggests that placing the patient in the feet down position for a moment, while the chest is compressed, should help the right heart to expel its blood so that, when the patient is again inverted, arterial blood may find its way to the central nervous system and heart, and so promote their functions. He further insists that if need be the manœuvre should be repeated. Hill's views are supported by sound physiological data which are undeniable. I have had, however, no opportunities of verifying his conclusions. There would seem to be some risk in raising the head of a patient, but possibly this danger is less than that of inversion if, as Hill insists, the blood cannot pass the heart and reach the nervous centres until the right ventricle is relieved of its distended condition. I believe heart massage to be a safer procedure performed by the incomplete method of Maas and Koenig, or by the complete system, although in some cases the latter involves a surgical operation and compression of the heart by the hand in the abdomen. This plan is described below.

When in performing artificial respiration the thorax is grasped in expiration, it is well to slip the hand under the costal border on the left side, and so mechanically excite the heart. The chest

and throat, bared of all clothing, should be slapped with a towel wetted in cold water, and fresh air from an open window allowed free access to the patient. Hypodermic injections of strychnine, although of more value when the respiratory centre is at fault, are regarded by some as a valuable method in all cases of chloroform poisoning. Dr. Crile, however, asserts that strychnine is useless in small doses, and in large ones may increase the fall of blood-pressure, and so do actual harm. Digitaline is probably a more efficient remedy, although it is less a respiratory excitant than is strychnine. The injection of brandy in *hot* beef-tea or in warm saline solution by the rectum is a useful measure in the less serious cases.

Maas recommends rapid percussion with pressure over the cardiac area. He compresses 100 or 120 times in a minute. Laborde's method of rhythmic traction upon the tongue finds many advocates. The tongue is seized and dragged forward out of the mouth as far as possible, it is then allowed to fall back, and again brought forward, the manœuvre being repeated 16 to 20 times a minute, or even more rapidly. I am doubtful whether adrenalin should ever be used in cases of chloroform poisoning, since recent work indicates that the former drug is dangerous in the presence of chloroform. However, Manskowski advocates and has successfully used intravenous injections of sterilised freshly-prepared supra-renal **extract.** Schäfer also regards **supra-renal** extract as the most powerful constrictor of the vascular system we possess, and places it with nicotine in the front rank among restoratives in cardiac syncope. The best way of employing the former is to mix 1 or 2 drms. of the 1 in 1,000 solution **adrenalin** in a pint of normal saline * and inject into a vein or into the subcutaneous cellular tissues. Pituitary extract (infundibular) is believed by many to be the best antidote to shock under chloroform. The dose suggested is 0·5 to 1 c.c. of a 20 per cent. extract, representing 0·1 to 0·2 grammes of the fresh infundibulum. It is injected hypodermically, preferably into muscles, to avoid local sloughing with the cellular tissues. The initial rise of blood-pressure following its use may be maintained for hours, but successive injections produce less reaction. The experience gained in war surgery

* Dr. Hare (*Practical Therapeutics*, 1905, p. 537) recommends the following saline solution: Calc. Chlorid. 0·25, Pot. Chlorid. 0·1, Sod. Chlorid. 9·0, Sterilised Water 1,000 c.c.

has cast doubt upon the views previously held in favour of the use of adrenalin and pituitrin in cases of shock with depression of blood-pressure. The subject is discussed more fully in Chapter X, and to this the reader is referred.

The inhalation of **nitrite of amyl** is vaunted as a specific, and certainly I have seen it do good in cases of syncope occurring late in narcosis, or after an operation when much blood-loss had occurred. The most convenient way of using the drug is to break a ℥iij glass capsule and hold it beneath the patient's nose, taking care that artificial respiration is maintained so as to ensure the due entrance of the vapour into the lungs. There seems, however, no satisfactory evidence which proves that amyl nitrite is in any sense an antidote to chloroform.

Among other measures advocated for counteracting this syncope must be mentioned **electrical stimulation** of the heart, and **acupuncture** of that viscus. One electrode is placed over the neck behind the sternomastoid at about the junction of its lower and middle thirds, while the other is wiped over the præcordium. This plan is, however, open to the objection that the electrical stimulation may produce cardiac inhibition by direct action upon the heart muscle. Stimulating the diaphragm to contraction may possibly aid respiration. **Acupuncture** of the ventricle with a gold needle is believed to act by exciting the heart to contract through direct mechanical stimulation. The results obtained in cases when this has been done have not so far been encouraging.

Massage of the heart by direct manipulation has been practised in a considerable number of cases, but without uniform success. In some instances, especially when heart failure has occurred during the performance of an abdominal section, the heart has been grasped from below and compressed rhythmically with a kneading motion of the fingers. In others the abdominal parietes have been divided and access obtained to the heart from below ; while in certain cases the more formidable operation of resecting the ribs and a portion of the sternum over the pericardium has been undertaken. The heart movements were restored in all cases, and as long as artificial respiration was kept on the circulation was maintained. In most of the cases, however, respiration eventually failed and consciousness was never restored. Dr. Babcock has used a far simpler method. He makes a stabbing incision on the sternal side of the heart in the left fourth inter-

space one inch from the sternum, and introduces a finger which is hooked round the apex of the heart, that viscus being rhythmically compressed against the chest wall. Heart massage is more fully dealt with in Chapter X.

Syncope arising late in the course of an exhausting operation must be counteracted by the methods described above. Brandy may be rubbed over the tongue, lips, and gums, and, as soon as the patient has rallied sufficiently to be able to swallow, may be given in sips in hot, strong beeftea. Sinapisms applied over the præcordium, epigastrium, and calves of the legs assist in producing reaction. The head should be kept low for some hours, and no attempt at sitting up allowed. Hot water or, better, hot saline (at 110° F.) injections into the bowel are of great value ; they must be copious and may be repeated. Reaction is aided by hot-water bottles applied to the feet and sides, and the flow of venous blood is promoted by firm rubbing of the limbs from the feet and hands towards the trunk. Inversion of the body, so that the feet are in the air, is often of signal service in extreme cases of cardiac weakness, *when there is no reason to believe that the right side of the heart is engorged.* Sniffing " smelling salts " or ammonia vapour will often assist, but the latter must not be too strong or it will excite spasm of the glottis. Bandaging the lower limbs and abdomen and firm pressure over the abdominal aorta are useful in these cases.

During abdominal sections patients are especially prone to syncopal attacks under chloroform. These are due (1) to interference with the normal intra-abdominal pressure ; this occasions draining into the abdominal veins, and hinders the passage of blood into the heart ; (2) reflex interference with the heart arising from dragging upon the viscera, and especially from pulling upon the omenta and reflexions of the peritoneum. In such cases pressure applied to the abdominal aorta has proved of value. As soon as the parietes are sewn together again the patient's condition improves.

Epileptic and **epileptiform** seizures are very liable to occur as patients pass under the influence of chloroform. Beyond transitory weakening of respiration and fall of blood-pressure, as a rule no ill consequences occur, but fatalities have occurred. It is well in the case of known epileptics to place a gag in the mouth to avoid the tongue being bitten.

After-effects of Chloroform.*

Bronchitis occasionally follows the inhalation of chloroform, and must be treated on general principles. In all such cases it is difficult to eliminate contributory circumstances, *e.g.* exposure, chilling of the body, etc. Lung complications may follow the use of partly decomposed chloroform (*vide infra*).

Vomiting.—If attention has been paid to the directions given when dealing with " The Preparation of the Patient," vomiting will be rendered less liable to occur. The following further directions will tend to the same end. Bilious, plethoric persons should have their bowels well cleared before taking chloroform and should be accurately dieted for some days before. The patient should not be moved from the operating-table for half an hour after coming to himself, and then the utmost care must be taken to prevent his being shaken or disturbed. Unless the patient's condition or the necessities of the operation contra-indicate it, the patient should be placed in bed with his head and shoulders raised.

Opium should not be given by the mouth ; and unless there is obvious and urgent shock, brandy, ether, and sal volatile had better be withheld. Nor should food be taken, whether liquid or solid, for at least three hours after taking chloroform, and even subsequently abstinence from everything except hot water, which may be taken copiously if vomiting or nausea is trouble-some, is best for six hours or so. Meat jelly, bread boiled in milk, a pinch of bicarbonate of soda being added, or sponge cakes soaked in a light dry sherry, may be permitted after this time ; tea, coffee, soaked toast, may be tried, but all indigestible or solid food should be withheld.

In cases of persistent **vomiting** or **nausea** sips or draughts of very hot water will give most relief, especially if bicarbonate of soda or citrate of potash is added. Thirst is sometimes a pain-ful after-effect following very prolonged operations. This is especially so after abdominal sections. Copious enemata of hot water, frequently repeated, are of value. Lavage, performed at the close of the operation and before consciousness returns, is often most valuable, especially for persons who are prone to severe sickness. Drop doses of Tr. Nuc. Vom., well diluted with hot water, are certainly useful in less severe cases. Mackenrodt

* For the medical treatment, see also After-effects of Ether, Chapter IV.

soaks a towel or handkerchief in cider vinegar, and arranges it so that the patient inhales the fumes. Essence of bitter orange peel used similarly checks sickness and assists elimination. In obstinate vomiting sinapisms over the stomach, small doses of Cocaine Hydrochlor. (Ⅲ v of 5 per cent.), oxalate of cerium, and codeia are valuable. Chloretone has been vaunted for the purpose of checking sickness, but it is less valuable when given *after* chloroform than when administered in gr. xv doses one hour and a half before the inhalation.

Fifteen-grain doses of Aspirin given in saline by the rectum immediately after the completion of an operation sometimes checks the tendency to vomiting in nervous persons and produces a refreshing sleep.

Dryness of the tongue, sometimes a troublesome complaint in the post-anæsthesia stage, is greatly relieved by Tinct. Myrrhæ, Glycerin. Boracis, or by sucking a piece of gauze soaked in Glycerin. ʒj ; also Spir. vin. rect. and water in equal parts, ʒij (Kelly). Thirst and tongue dryness, especially frequent after operations upon abdominal viscera, are best treated by copious rectal injections of warm water given every three or four hours. It is stated, but I have no personal experience in the matter, that if patients are allowed to drink hot water up to two or three pints previously to the time that the anæsthetic is inhaled, they are less sick and suffer from no nausea. The last glass of water is allowed half an hour before the anæsthetic. When morphine is given after chloroform has been inhaled, the vomiting is certainly worse. It is altered in type, usually occurring after an interval of some twelve hours or so, and is commonly very severe.

Post-operation shock,* in so far that it may in part be due to the anæsthetic, needs careful attention. The patient lies cold, with clammy extremities, feeble pulse, and faint, sometimes irregular, respiration. Consciousness is slow in returning. The horizontal posture, application of warmth to all parts of the body, enteroclysis, rubbing brandy into the lips and buccal pouches, with constant friction applied to the legs and chest, are the best means of restoring the patient. I have found hypodermic injections of strychnine, and oxygen inhalations of the greatest value in these cases. In extreme conditions of shock,

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* The subject of Shock in association with anæsthetics is dealt with more fully in Chapter X.

transfusion of normal saline is called for and will often restore an apparently hopeless case.*

Poncet has drawn attention to the dangers of the period of recovery from an anæsthetic. In more than one case patients whose respiration failed, owing to malposition after they were placed in bed, were recovered by his performing tracheotomy and ventilating the lung through the aperture so made. This plan succeeded when all the ordinary measures, e.g. artificial respiration, etc., had been tried and failed. Poncet explains the mechanism by which death is averted in these cases by the following ingenious hypothesis. Under normal conditions the lungs are expanded sufficiently to overcome the resistance caused by their elasticity and the obstruction in the air-passages. Under an anæsthestic, while some inspiratory power remains, the expirations grow rapidly more feeble. The muscular structures undergo paresis. At this point even a slight obstruction, fixation of the jaws, falling back of tongue, glottic spasm, or even a collection of mucus, will be too much for the respiratory mechanism to overcome, and asphyxia results. Tracheotomy, although but slightly increasing the patency of the air-way, will, Poncet believes, by allowing *cold* air to enter, excite reflexly more vigorous respiratory movements.†

After-effects due to decomposition of chloroform during operations undertaken by gaslight are those arising from inhalation of irritant gases—phosgene gas, chlorine, hydrochloric acid fumes—and the treatment consists in assisting the elimination of the gases by opening windows, etc., and allaying the bronchial spasm by bland inhalations, while the concomitant shock is treated on general principles. The danger is increased when the room is small and when the atmosphere is foggy. Several deaths have occurred, resulting from phosgene gas poisoning.

Hysteria.—Fits of hysterics are sometimes excited in the neurotic by chloroformisation ; no special treatment need be adopted. These attacks seldom last more than three or four hours, and should cause no alarm. In rare instances such seizures simulate acute mania, although the latter is more common after the use of ether. The greatest care has to be

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* The gum solution recommended by Professor Bayliss is probably better for this purpose since it does not escape so readily from the blood-vessels.

† See *Lyon Médicale*, Jan. 13 and June 16, 1895, pp. 35, 49, and 226.

exercised to avoid the patients doing themselves damage by their struggles. Sedatives given by the rectum or hypodermically are called for in really bad cases. Such attacks may occur in either sex.

Jaundice and general biliary derangement in some instances follow chloroform administration, especially after prolonged or repeated administrations. They should be treated upon general principles, and usually need not give rise to alarm. We must not, however, lose sight of their possible connexion with delayed chloroform poisoning.

Glycosuria and albuminuria may follow the use of chloroform. According to Baixer, diabetics are injuriously affected by chloroform. In 24 or 48 hours they become restless, then drowsy, and finally pass into coma and die. Although such results do not necessarily follow, as my experience has taught me, yet I think in severe cases of diabetes it is wiser to adopt spinal anæsthesia whenever it is possible. Amputations for diabetic gangrene can often be done under local analgesia, with or without the use of alkaloids, and gas with oxygen. When chloroform is employed as little as possible should be given and the operation should be performed rapidly.

Upon the renal epithelium, chloroform excites a marked action. Legrain found albuminuria and cylindruria fairly common after chloroform inhalation, and more persistent although less in amount than after ether. Thomson and Kemp are led to believe, as a result of oncometric observations, that suppression never follows the inhalation of chloroform, and that the albuminuria is slight and transient. Wunderlich, Alber, and Rindskopf, however, agree with Legrain. When pre-existing renal disease is present, chloroform should be given very sparingly to limit its action on the kidneys. Working with the oncometer I found in the case of dogs that the results of chloroform upon the kidneys were materially affected by the strength of the vapour given. The treatment should be conducted on general lines.

Delayed chloroform poisoning (so-called Acidosis).* — An extremely curious sequela has been closely studied by Leonard Guthrie and others in this country, and by Brackett, Stone and Low, Baird, Favill and Bevan in America, and by many workers

* The subject of Post-operative Poisoning by chloroform is so intimately connected with Shock that the reader is referred to Chapter X in which both conditions are discussed.

abroad.   It has been known for a long time that a degeneration
of the liver and other viscera takes place in dogs when they are
compelled to inhale chloroform at frequent intervals.   It is
now recognised that similar pathological changes, affecting
especially the liver, kidneys, heart, and muscular structures,
may be brought about under certain conditions in human beings,
as a result of even one inhalation of chloroform.   The symptoms
usually appear between the 12th and 42nd hours after the inhala-
tion.   They are : repeated vomiting of foul watery fluid, which
later is brown, and resembles dregs of beef-tea ; restlessness,
delirium, or excitement, alternating with an apathetic state,
which may deepen into coma.   The breath has a strong odour
of acetone.   The urine is scanty, albuminous, contains casts,
while acetone, diacetic acid, or β-oxybutyric acid are sometimes
present in it.   At length respiration and circulation fail, and death
closes the scene.   How far chloroform is responsible for the
development of this condition it is impossible to say.   It is
clear that the anæsthetic is not the sole factor, as out of the many
thousands of persons who inhale chloroform, extremely few
patients reveal the symptoms of this intoxication with its charac-
teristic pathological lesions.   Nor can we trace any antecedent
condition common to the patients.   It is true that more instances
of children so affected have been reported, but this may be
explicable upon other grounds.   The main points of practical
importance seem to be that *limiting the amount of chloroform
inhaled and restricting the strength of the vapour* are the surest
safeguards against this toxic condition in chloroformed patients.
The treatment of these cases has been carried out on general lines,
and in some instances has proved successful.   The most recent
work done upon this subject appears to warrant the belief that
the condition arises through interference with carbohydrate
metabolism, and that the most hopeful treatment is to give
glucose either by the bowel ($\mathfrak{Z}$i to $\mathfrak{Z}$vi of saline) or by the mouth.
The phrase " delayed chloroform poisoning " is a bad one, because
the condition may follow ether or ethyl chloride, and, indeed,
as Dr. Frew * has shown, changes in diet will induce acidosis in
poorly nourished children.   I have discussed this subject more
fully in a paper contributed to the *Transactions of the Medical
Society*,† and to this the reader is referred.   Dr. William Hunter's

* *Trans. Roy. Soc. Med.*, Section " Anæsthetics," 1912.
† Vol. xxxv. p. 280.   See also *Lancet*, May 11, 1912, p. 1267.

work upon this subject is of great value ; he appears to regard the perversion of function as largely due to injudicious food selection and limitation, and to place the effect of an anæsthetic as one factor only, and that not a dominating one, in causing the toxæmia. It is interesting, in this connexion, to notice the—

Effects of repeated inhalations.—Paul Bert made a careful study of the effects of daily administration of chloroform for a definite time. His researches were made upon dogs. After gradual failure of health, these animals died on the 32nd day with well-marked wasting of their organs and muscles, and fatty changes in the liver. Parasporo (*Il Policlinico*, Dec., 1897) has repeated these experiments and met with similar results. He further reports finding a similar fatty change in the tissues of a woman who died from an overdose of chloroform. According to J. Regnault and Dubois (quoted by Dastre), workers constantly exposed to the fumes of chloroform suffer from insomnia, with neuralgic and rheumatic pains, as well as marked physical and mental depression. The post-mortem changes seen after delayed chloroform poisoning closely resemble those met with in persons dying from septic intoxication.

ASTIGMATISM and INSANITY, although recorded as after-effects of chloroform inhalation, are probably the results of general disturbance.

CHLOROFORM IN VETERINARY SURGERY.

It is hardly necessary to emphasise the importance of using anæsthetics in most operations upon the lower animals. In the case of horses, dogs and cats, especially, surgical procedures can be better done, while shock is lessened when anæsthesia is complete. It is equally important if valuable lives are to be saved that dosimetric methods should be employed. The animals are supremely affected by strong vapours, and they are also liable to fatal syncope when in a semiconscious condition. Mr. Hobday's apparatus fitted with appropriate face-masks is better than the douche method and the bucket masks commonly employed, and should be adopted in preference to these. In the case of small animals which are savage it is often necessary to induce anæsthesia while the patient is in a box, but even then it is quite simple to pump in the required strength of vapour and maintain anæsthesia by means of the mask when the animal

has been removed from the box. Giving evidence before a Departmental Committee on the compulsory giving of anæsthetics to the lower animals when they have to be operated upon, one witness made the astounding statement that chloroform could not be safely administered to them, and so the operation should be done without an anæsthetic ! This is grotesquely untrue. Chloroform or ether can be taken by cattle, horses, and dogs and other animals quite well, provided reasonable care is taken and suitable methods are employed.

One form of the Hobday apparatus is shown on page 262.

ETHYL CHLORIDE, ITS MIXTURES—ETHYL BROMIDE AND THE LESS COMMONLY USED ANÆSTHETICS.

Ethyl chloride (Chlorethyl) is employed both as a local and as a general anæsthetic.

Preparation.—Ethyl chloride, C_2H_5Cl, is prepared by passing carefully dried hydrochloric acid gas into a flask containing absolute alcohol to which coarsely powdered anhydrous zinc chloride has been added ; the zinc chloride is a powerful dehydrating agent, and combines with the water produced during the reaction. The flask is fitted with a reflux condenser, and is gently warmed on a water-bath ; the gaseous ethyl chloride is passed through wash bottles to purify it, and is then collected in a U-tube immersed in a freezing mixture.

If prepared from industrial methylated spirit, it will contain a small proportion of methyl chloride.

Physical and chemical properties.—Ethyl chloride is a gas at ordinary temperature and pressure, but when slightly compressed is a colourless mobile liquid with a pleasant ethereal odour. The specific gravity is about 0·921, and the boiling-point 12·5° C. It is very inflammable and burns with a smoky, green-edged flame.

It is generally kept in glass tubes, sealed, and fitted with a spray nozzle.

It should be free from hydrochloric acid and alcohol. The following are the principal tests :—

Hydrochloric acid.—Water which has been shaken with twice its volume of the liquid should be neutral to litmus and should produce no turbidity when added to a solution of silver nitrate.

" Smell " test.—When 10 c.c. are sprayed upon filter paper no foreign odour should be perceptible during the evaporation, and when all the ethyl chloride has volatilised the filter paper should be quite odourless. This test will usually detect impurities occurring through careless storage.

Alcohol test.—When 10 c.c. are shaken with 10 c.c. of dis-

tilled water, the lower aqueous layer boiled with a few drops of diluted sulphuric acid and a few drops of potassium dichromate solution, should develop no odour of aldehyde, and no greenish colour should be produced in the liquid.

Quantitative test.—When saponified by heating with standard alcoholic potassium hydroxide and the excess of alkali estimated with standard acid, the result should indicate the presence of at least 99·5 per cent. by weight of esters calculated as ethyl chloride.

Kelene and **Chloryl Anæsthetic** are trade names for ethyl chloride.

Anestile (Anæsthyl) and **Coryl** are designations given to mixtures of the methyl and ethyl chlorides. They are more volatile than ethyl chloride.

History.—Although ethyl chloride has been adopted as a general anæsthetic only within the last few years, it was known and employed as early as 1848 by Heyfelder. Benjamin Ward Richardson included it in his " Synopsis of Anæsthetics," published in 1885, and gives 1849 as the date of its introduction by Nunneley, and 1852 as the year in which, conjointly with Snow he demonstrated its value as an anæsthetic. The " Glasgow Committee " of the British Medical Association examined its action upon the lower animals and arrived at the conclusion, which they formulated in their Report published in 1880, that it was unsuitable for human beings, as it produced convulsions and respiratory failure. Its restoration to favour was due to the observations of Carisen and Miesing, who, when employing it as a local analgesic, found it induced general anæsthesia. Lotheisen used it systematically as a general anæsthetic, and to his writings we owe much of our knowledge of this agent. The disrepute into which the drug had fallen was due to the impurity of the samples examined. Even now certain of the preparations give unsatisfactory results, so that care must be taken to obtain the anæsthetic from reliable makers. Some foreign manufacturers have attached fancy names to ethyl chloride and its mixtures. This procedure is undesirable as it suggests that the preparations possess special powers and masks the true character and properties of the drug employed, while the advertisers are apt to vaunt their nostrums as free from danger.

Physiological action.—Profound narcosis with complete anæsthesia are rapidly produced by ethyl chloride when given

with strict air limitation. Lebet, working with Dumont of Berne, found that intravenous injection produced marked circulatory depression in the case of rabbits. This agrees with the results at which Wood and Cerna arrived. Malherbe and Roubinovitch found the arterial tension in man was lessened in most cases. Koenig's results are in accord with their conclusion ; and McCardie, who in this country has done much valuable pioneer work upon this subject, has satisfied himself that a fall of blood-pressure takes place when ethyl chloride is given even for a short time. Seitz's sphygmographic results reveal a rise of arterial tension. Probably the truth lies between these extremes of opinion, and some observations of Koenig may explain the discrepancy. He showed that when air was completely excluded arterial tension rapidly fell, and death ensued from failure of respiration and circulation. In clinical work this exclusion of air is either avoided altogether or only practised for a very brief time, so that the arterial pressure does not undergo any material change.

Flushing, due to dilatation of peripheral vessels, is always associated with ethyl choride inhalation, and may account in part for any fall in blood-pressure which may take place. Respiration is profoundly affected, but this is possibly secondary to the changes in the circulation, except perhaps when large doses are employed. Seitz, however, takes the opposite view, believing respiration to be affected first. Respiratory paralysis and failure of the heart's action result from the inhalation of a full dose of this drug, especially when the supply of air is much limited. Koenig asserts that in complete anæsthesia vagal inhibition is abolished. The nausea and vomiting which so frequently follow the use of this anæsthetic are probably due to reflex causes rather than to a direct irritant action upon the mucous membrane of the stomach. Its action is very fugacious ; patients rapidly lose and soon regain consciousness. Its elimination takes place mainly through the lungs ; but, as Lebet has pointed out slight albuminuria occurs, it is probable that when given for a prolonged period some of the drug passes through the renal tissues. Its action as a local analgesic is due to its causing ischæmia and paresis of the terminals of the sensory nerves.

Danger and death rate.—It is extremely difficult to arrive at an accurate estimate of the safety of ethyl chloride. Ware

collected 11,207 cases and reported one death. Seitz and Konstanz place the death rate at 1 in 16,000. Several deaths have occurred in Great Britain. It is certain that ethyl chloride is less safe than nitrous oxide, and must be placed between ether and chloroform for normal patients, but may be regarded as possibly safer than ether when lung and kidney complications exist. Some authorities, however, assert that ethyl chloride is safer than nitrous oxide and other anæsthetics when given to quite young children. Our present knowledge of ethyl chloride, however, makes us recognise that it is by no means so safe as at one time it was believed to be. In the hands of the experienced it is no doubt a fairly safe anæsthetic, but not one to be employed by the inexpert and incautious. McCardie's experience tends to confirm this. He very wisely insists upon our recognising the limitations of its range of usefulness. My own experience, which is now extensive, leads me to believe that ethyl chloride is comparatively safe in suitable cases when properly given, but may easily produce serious symptoms. I have never seen a death, but have experience of two cases in which an alarming failure of respiration and circulation occurred. One patient was somewhat anæmic, but both were in average health, and there was nothing in the operations themselves or in the respective circumstances of these cases to have occasioned syncope. In each case complete anæsthesia was present, and a full dose of the anæsthetic was employed. The occurrence of serious complications, such as syncope, which in one case ended fatally, has been recorded by Ware, Lothiesen, and others. Respiratory failure is probably the most common accident, certainly so in the case of children, but danger may arise from the side of the circulation and is then more serious.

Preparation of the patient. — This should be the same as in the case of chloroform or ether. It is advisable that food be abstained from for four hours, and the last meal taken should be light and digestible.

Posture.—Unless the patient is very asthenic, the sitting or reclining posture may be adopted. The clothing must be loose, and everything which interferes with breathing removed.

Administration.—Ethyl chloride may be given by an " open " or by a closed method.

The open method.—A wire mask covered with one layer of flannel is fitted accurately to the patient's face. A light towel

is thrown over this after the ethyl chloride has been dropped on the mask. The tube of anæsthetic is arranged to drop by placing a tiny mass of cotton wool " the size of a quarter of a small split pea " beneath the lever which closes the minute outlet of the stopcock. The tube is tilted and ten drops of ethyl chloride allowed to fall on the mask. After a few seconds double this quantity is applied, care being taken to scatter the drops over an extended area of the mask. If this is not done freezing will occur, checking all evaporation. This procedure is repeated until unconsciousness supervenes. Anæsthesia is induced in about one minute and persists sufficiently long to enable a brief operation to be performed. Mr. Hornabrook of Melbourne, whose method is described above, assures me that few if any unpleasant after-effects arise and that he has seldom met with vomiting or discomfort. According to this observer a period of local analgesia follows the anæsthesia, enabling the operation to be completed even when the patient becomes conscious. 8 to 10 c.c is an average dose by the open method ; the resulting narcosis is light but adequate. The patient should be sitting up with the head placed in the axial line. When this method is adopted for longer operations a few drops of chloroform are used immediately after the ethyl chloride, and these are followed by ether given by an open method. It is alleged that full surgical anæsthesia is thus obtained in two or three minutes. This plan has been carefully elaborated by Dr. G. A. H. Barton.* He commences with a little C.E. mixture, then uses ethyl chloride, and follows on with chloroform. It is well to place an unopened gag between the teeth before commencing the inhalation, opening it just before the operation, if this is necessary.

The closed method. — This method involves the use of an inhaler ; those depicted and described below are simple and efficient. The first, which has been modified by Dr. Beresford Kingsford from Mr. Boyle's wide-bore inhaler (with lint lining the inside of the mask), ensures that the breathing shall be free and unrestricted. The " Ideal " is the suggestion of the late Mr. Vernon Knowles, and is supplied with his reversible rubber bag which enables the anæsthetist to ensure cleanliness in his work. The " Simplex " is from the design of Dr. Luke, of Edinburgh, and is excellent.

Many inhalers, too numerous for mention and each possessing

* *Practitioner*, Sept. 1907.

some merit, are to be obtained. Of these several are simple adaptations of Clover's regulating ether inhaler. When no special inhaler is employed, a ready substitute can be made by having an opening bored into the metal-carrying mount of the rubber bag of the " Clover," to allow of the ethyl chloride being introduced into the bag. The aperture can be closed by a wooden plug. The mount carrying the bag is then fitted directly on to the face-piece, the ether chamber being discarded unless the sequence of ethyl chloride and ether is to be employed. The opening made in the mount serves for spraying in the ethyl chloride and is made just large enough to take easily the nozzle of the stopcock on the ethyl chloride tube. It is quite simple to make an inhaler from lint or a towel folded into a cup-shape ; although, as a rule, the device is less satisfactory, it serves its purpose fairly well in the case of very young children, and in that of extremely nervous patients, who dread the application of any formal inhaler.

Ethyl chloride may be given also : (1) in sequence with nitrous oxide ; (2) in sequence with ether ; (3) before chloroform ; (4) in various mixtures. These last are : different admixtures of methyl and ethyl chlorides, with or without ethyl bromide.

Indications and contra-indications for its use. — Ethyl chloride may be used for children from five days old and upwards with good results.*   I have employed it for the aged † as well as the very young, and without difficulty or danger. Dr. McCardie considers that conditions causing blocking or stenosis of the air-passages are contra-indications, and with this I agree. Among diseased subjects my experience is that, while no chronic or acute disease, as such, is a contra-indication, yet lung diseases involving marked respiratory difficulty, especially when associated with bronchorrhœa, are liable to cause dangerous developments when ethyl chloride is given. In a case of aortic aneurism in which I administered this anæsthetic, the narcosis was free from any unfavourable symptoms.

When complete muscular relaxation is required, my experience has not been favourable to ethyl chloride. Dr.

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* Dr. Flora Murray adopts it as a routine method for such patients and speaks enthusiastically of it, *Lancet*, Nov. 25, 1905.

† In the case of those advanced in years great care is needful, and the recumbent posture a *sine qua non*.

McCardie does not agree with this view, and contends that, with care and an adequate dose of the drug, muscular relaxation can be usually obtained.   Spraying a few c.c. of ethyl chloride on the open mask when chloroform is in use is said to hasten relaxation, and the like result follows in the case of ether given similarly. I have no experience of ethyl chloride in midwifery practice, but it has been employed, and, it is stated, with success.   Alcoholic persons are not good subjects for ethyl chloride.   They are apt to become extremely violent, and often the anæsthesia in their case is very brief.   In some instances it is extremely diffi-
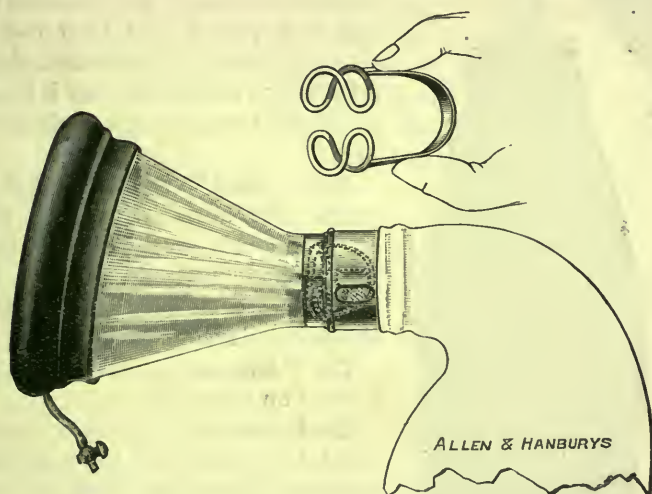
FIG. 74.—Wide-bored ethyl chloride inhaler (Kingsford).

cult to produce a satisfactory and quiet anæsthesia, even when using a large dose, *i.e.* 10 c.c.   Smokers suffering from pharyngeal catarrh do not always take this anæsthetic well ; they are liable to cough, strain, and struggle for air.   When the heart's action is feeble and the weakness is probably due to fatty degeneration ethyl chloride is contra-indicated.

DESCRIPTION OF INHALERS.

Wide-bored inhaler.—In Dr. Beresford Kingford's improved form of Mr. Boyle's inhaler there is no lint in the face-piece, so that the patient's face can be seen throughout the administration.   The neck of the bag fits over that of the face-piece, and can

be freely rotated about it. Corresponding openings are made in the inner and outer necks, and when these coincide the anæsthetic can be sprayed through them into the bag. Within the neck of the face-piece a piece of lint can be fixed (opposite the

aperture) by a clip, so as to form a pocket which is open towards the bag. The lint minimises reflux of the spray into the face-piece, and economises the anæsthetic. When a gag is used the inhaler can be applied *uncharged* the moment the gag is adjusted, and then can be charged during an inspiration. After a breath or two the air-way is closed by slightly rotating the neck of the bag.

The "Ideal" is constructed to enable the administrator to give ethyl chloride freely diluted with air. I have little doubt, from my experience with this inhaler, that the principle is a correct one.

The "Simplex" inhaler (Luke) is figured on this page.

The inhalation (1) for short operations, *i.e.* such as can be performed when one, or at the most two, inhalations are allowed. The patient should be seated comfortably, his body and legs disposed as in the case of nitrous oxide (see Plate II.). A dental gag should be placed securely in position, and the face-piece carefully applied with the supply aperture open. There

FIG. 75.—The "Simplex" inhaler * (Luke).

must be most accurate co-adaptation, so that *no air enters under the inflated rim of the mask*. A few breaths having been taken, 3 c.c., in the case of an adult, are then sprayed into the bag at the end of a forcible expiration. The inlet is then closed, and the patient encouraged to breathe freely. If he holds his

* Made by Messrs. Duncan & Flockhart.

breath, as may happen with nervous patients, the chin should be sharply jerked upwards, as this induces an inspiration. After fifteen or twenty seconds, when the breathing has become fuller and more rapid, the inlet is again opened at the end of an expiration, and 2 c.c. more of ethyl chloride are sprayed in. If a prolonged anæsthesia is desired, and the patient is vigorous and full-blooded, 3 c.c., or even 4 c.c., may be given instead of the 2 c.c. The plan of dividing the dose, which I have adopted and described, is based upon the following observation. Patients when they commence breathing ethyl chloride often breathe feebly, and do not inspire the full dose from the bag. As, however, they become partly narcotised the respirations grow more vigorous, and the second dose, which is then sprayed into the bag, is inspired freely, and thus a good and prolonged anæsthesia is ensured. In thirty to sixty seconds from the commencement of inhalation the breathing will become loudly and musically stertorous. The stertor deepens ; in most cases the eyeballs will be fixed—being usually rotated downwards—and the pupils dilate ; the anæsthesia is then complete. The degree of insensibility is very profound, yet, if the anæsthetic is withdrawn as soon as well-marked stertor is present, it will deepen for a few seconds afterwards. This deepening of narcosis after the mask is withdrawn is very considerable in children of any age under seven years. The corneal reflex is lost, the crying subsides, and the reflex will only return after an operation has been performed without evoking a struggle or sign of consciousness.

If, in such young children, the anæsthetist waits for cessation of crying, or is induced to give more anæsthetic to effect deeper narcosis, failure, or danger from overdose, will certainly be incurred. The duration of anæsthesia is usually from one to three minutes. In one instance I obtained a period of five minutes' anæsthesia, using 8 c.c. of the anæsthetic.

That the action of ethyl chloride is very fugacious is shown by the rapidity of recovery. For a few seconds after anæsthesia ceases the patient is dazed and has little control of himself or his movements, but this is followed by restoration to complete consciousness. In these respects ethyl chloride resembles nitrous oxide and contrasts with chloroform or ether narcosis. As soon as stertor begins, the mask should be removed and the operation commenced, for if the anæsthetist delays removal of the mask with the view of obtaining a longer anæsthesia, he will

find, to his chagrin, that during the delay the ethyl chloride has partly or wholly disappeared and consciousness is returning.* If, after the inhalation has lasted sixty seconds, there is no stertor, more anæsthetic must be given, as the narcotic effect is never delayed beyond this point. It is important to remember that the narcosis, while it lasts, is very deep and the reflexes are in abeyance, and thus operations on the upper air-passages involving hæmorrhage may prove dangerous (or even fatal), unless care is taken to direct the blood out of the mouth.

(2) Prolonged operations. Although the consensus of opinion is not in favour of the use of ethyl chloride for longer operations, except sometimes in the case of young children, yet it may be well to indicate the technique of its management for operations of from five to twenty minutes' duration.

The patient must be carefully prepared, just as in the case of ether or chloroform. The induction is conducted as has been described above, and when anæsthesia is obtained the mask is either removed or the inspiry valve opened, the patient being permitted to ventilate the lungs with air. As soon as stertor disappears and the eyeballs commence to move, 3 c.c. or 4 c.c. are sprayed into the bag. This is repeated as often as may be necessary to maintain anæsthesia.

It is seldom advisable to give more than 5 c.c. at one time, although in the case of alcoholics and vigorous men it may be necessary to use 3 c.c. or even 5 c.c. after the initial dose before anæsthesia is obtained. As a rule, 3 c.c. are sufficient for children and 5 c.c. for adults. It is, however, important to ensure that this dose really enters the patient's lungs. To this end the mask must fit accurately, the patient must be encouraged to breathe freely during the induction, and the respirations must be sufficiently vigorous to nearly empty and refill the bag. Children, especially young and feeble children, cannot do this, and so when the anæsthetic is not sprayed upon lint or a sponge near to their mouths they do not get enough of it. This difficulty is met by the lint in the inhaler (as in Mr. Boyle's pattern), but it can easily be overcome by placing the hand under the bottom of the bag of the inhaler; this volatilises the ethyl chloride.

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* It is often very difficult to avoid slight leakage between the mask and the face of the patient, and even if this is very slight, it will be sufficient to dissipate the anæsthetic.

Ethyl chloride in operations upon children. — Dr. Flora Murray * regards this anæsthetic as preferable to chloroform for children. A simple bag with celluloid face-piece, fitted with a wire holder to keep a piece of lint in position and an aperture in the connecting shaft, are all that is required. A dose of 3 c.c. is suitable for infants of a few months old and 5 c.c. for children a few years old. The mask is held near, but not touching, the face for the first breath or two. The ethyl chloride is sprayed on to the lint ; it is then applied closely. The child should **not** be held more than is necessary to prevent his hands from clutching the inhaler. Stertor appears in a few seconds, the eyeballs are fixed, and deviation is commonly seen, the pupils are variable, and the respirations are rapid and deep. As recovery comes on these grow slower and more shallow. Repeated doses may be given, respiration being closely watched. If it begins to fail, the chest should at once be compressed and the anæsthetic withheld until breathing is fully restored. The after-effects are usually slight.

METHODS OF GIVING ETHYL CHLORIDE IN COMBINATION.

With nitrous oxide. †—The ethyl chloride is sprayed into a tube or bottle, which is attached by an indiarubber tube to a tap in the distal end of a Cattlin's gas-bag after this latter has been partly filled with nitrous oxide. Experience is necessary to gauge the quantity of gas requisite for each patient. The patient inhales the gas, and after a few respirations the expiry valve is closed, and rebreathing takes place for a few seconds ; then the stopcock is opened and the ethyl chloride is allowed to evaporate, or, if necessary, is tilted into the gas-bag. My experience of the method has not convinced me of its superiority over simpler procedures, except when it is desirable to give a patient nitrous oxide because he is already familiar with it, and yet obtain the more lasting and profound anæsthesia of ethyl chloride.

With ether.—Ethyl chloride may be used instead of nitrous oxide as a means of introducing ether. In the event of a closed

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* *Lancet*, Nov. 25, 1905, p. 1542.

† Sir F. Hewitt introduced this method at the Annual General Meeting of the British Dental Association, June 1903. See *Brit. Dental Assoc. Jour.* for 1903, p. 615.

ether inhaler being used, the method is quite simple. The induction by ethyl chloride is as described above, and ether is given as soon as stertor is well marked, at first in moderate strength, but rapidly increasing it to " full ether." Cyanosis may be produced if the ether is presented too soon, and is always a warning that a breath of air must be given. If an " open ether " method is to be used it is better to use a few drops of chloroform to deepen narcosis before commencing the ether. Before these sequences, alkaloids may be advantageously employed.

DIFFICULTIES AND DANGERS.—The dangers are **interference** with **circulation** and **respiration.** Very **young children** occasionally stop breathing during the period of induction. This, possibly, is the result of over-stimulation of the respiratory centre. The explanation is not, however, quite satisfactory, since blood-pressure in such cases is distinctly low ; but from whatever cause it arises, the complication, though an alarming one, fortunately seldom proves serious. The removal of ethyl chloride, lowering the head, and compression of the chest rapidly restart respiration.

In adults embarrassment to respiration, cyanosis, faintness or syncope may occur. Such accidents may arise through giving a large dose, such as 8 c.c. or 10 c.c. ; lack of attention to the correct posture for carrying on unimpeded breathing ; or from collateral circumstances which interfere with respiration, such as falling or pressing back of the tongue, *e.g.* during the extraction of lower teeth. Blood passing backwards to the larynx is again a cause of such dangers. Cyanosis, pallor, rapid, shallow, and laboured breathing, should be watched for and at once recognised as a warning of danger. The anæsthetic should be withdrawn, the head lowered, the jaw pushed forward, and if need be, the tongue seized and traction made upon it. In extreme cases, when there is actually cessation of respiration and of circulation, the patient should be placed in the horizontal position, the tongue held forward and the upper air-passages cleared of blood and secretions, and artificial respiration performed. Young children should be placed on the right side, and the chest rapidly compressed. If these measures fail and air is not entering the lungs laryngotomy may be required. The fatalities which have occurred have been due to the failure

of circulation and respiration.*   In cases in which circulatory failure occurs if inversion and artificial respiration fail to restore the heart's action, cardiac massage may be required (*vide infra*, Chapter X.).

After-effects. — Vomiting and **nausea** are more frequent after ethyl chloride than after nitrous oxide inhalation.   This is partly accounted for by the profoundness of the narcosis, which allows the swallowing of blood and mucus.   Provided that by attention to the position of the head and by efficient sponging out of the fauces this does not occur, it will be found that vomiting is by no means a necessary sequela.

In dental hospital practice I found 9·6 per cent. of patients vomited, and to these must be added 4·8 per cent. of cases in which there was some nausea or retching.   The cases examined were not prepared for the anæsthetic ; some had taken a meal, several had taken alcohol just before entering the hospital. It must be pointed out further that, in these cases, extensive dental operations were performed involving the removal of several teeth, and the blood effused was swallowed during the progress of the extractions before the patient was aroused, so that the figures given are probably the most unfavourable which could be cited.

Mixtures containing Ethyl Chloride.

Of these the best known are somnoform, narcotile, kelene, and anestile.   Somnoform consists of ethyl chloride 83 parts, methyl chloride 16 parts, and ethyl bromide 1 part.   In some makes the ethyl bromide is omitted, although the name is retained.   Somnoform with a slightly modified composition is known as sœmnoforme, and is described below.   Kelene, narcotile, and anestile are either ethyl chloride pure and simple, or are mixtures of it with methyl chloride.

* Cf. *Transactions of Soc. of Anæsthetists*, vol. vii. pp. 91, 99, 103, 119, 129.   See also below, Chapter X., " Accidents of Anæsthesia."   A typical death under ethyl chloride may be mentioned here.   The patient, aged 67, was given 5 c.c. for a dental operation, and died before its completion. It was discovered at the necropsy that he had a " fatty heart."   Unless an elderly patient is hale, and has no enfeeblement of circulation and no respiratory embarrassment, ethyl chloride should not be given to him, and certainly only when he is in the recumbent posture.

Sœmnoforme * is composed of methyl chloride 7 parts, ethyl chloride 12 parts, and ethyl bromide 1 part.

Sydney W. Cole † has undertaken, under strictly scientific control conditions, a research into the physiological action of this mixture, and finds its behaviour is in the main that of ethyl bromide. Dr. Swan ‡ has also conducted a limited research, while the originator of the mixture § has published his views on the action of somnoform.

Mr. Cole found somnoform increased the range and rate of contraction and heightened the tonus of the diaphragm ; large doses caused death by setting up powerful tonic contraction of the diaphragm with arrest of respiration, while the heart still beat strongly. This occurred also after the vagi were divided, and therefore was due to action on the respiratory centre. An initial rise in blood-pressure and acceleration of the heart beat were followed, when the dose was increased, by a fall of blood-pressure. The strength of the heart's contraction was lessened. No effect on the vaso-motor system was noticed. Animals usually struggled, even after complete loss of corneal reflex, and regular rhythmic movements of the muscles of the limbs, tail, and jaws persisted ; while muscular relaxation was seldom complete, even with large and dangerous doses. The pupil at first dilated, and subsequently contracted. Dr. Swan has examined the blood of patients before and after taking somnoform, and found no change in the amount of hæmoglobin, or in the number of leucocytes.

Now that these facts are established, it can hardly be wise to employ this mixture.

The administration is conducted in a similar way to that of ethyl chloride, but the greater strength and danger of somnoform claim more caution and the closest attention to symptoms.

* Introduced by Dr. G. Rolland in 1901 at the meeting at Ajaccio of the Congress of French Associations for the Advancement of Sciences (Odontological Section), and by him and Dr. Field Robinson at the Annual General Meeting of the British Dental Association at Shrewsbury, 1902. See *Brit. Dent. Assoc. Jour.*, 1902, p. 321.

† Proceedings of the Physiological Society, May 16, 1903, *Journal of Physiology*, vol. xxix. The reader should consult the paper by Dr. Adolf Haslebacher, " Experimentelle Beobachtungen über die Nachwirkungen bei der Bromæthyl und Chloræthylnarkose," Bern, 1901.

‡ *Proceedings of Society of Anæsthetists*, vol. vi., 1903, p. 49.

§ *Op. cit.*

Phenomena of narcosis. — The face flushes as with ethyl chloride, the pink-red deepens almost to cyanosis if large doses are given, the respiration is quickened, but grows weaker and less full, and faint stertor is usually heard ; the eyes become suffused and the eyeballs fixed in a position of deviation downwards and slightly inwards ; more rarely the deviation is upwards ; the pupils at first dilate, but later on, according to some observers, they become smaller. Dr. Kingsford, who has studied the changes of the pupil in 1,700 cases of somnoform anæsthesia, informs me he has never seen the pupil undergo contraction while the ocular globes remain fixed. After moderate doses the pulse is quickened, but is usually little altered in volume. If very full doses are administered, duskiness, distinct feebleness of breathing, with quick collapsing pulse result. Anæsthesia is present when the breathing is stertorous, and the mask should then be removed, but in the case of children this should be done even if the conjunctival reflex is present, and the ocular globes are still moving. The depth of narcosis is increased for some seconds after the patient ceases to inhale ; indeed in very young children the narcosis may continue to deepen for half a minute or even more, and this must be allowed for in determining the right moment for withdrawal of the anæsthetic.

After-effects. — Much difference exists in the statements of those who have had large experience with somnoform as to the after-effects produced by it. I think, however, that there is little doubt that nausea, vomiting, and severe headache are common sequelæ. The patients are commonly dazed for some minutes after the inhalation, more so than after ethyl chloride.

Difficulties and dangers. — Unless air is almost completely excluded, no anæsthesia will result. A mistake which results in failure is often made, *i.e.* keeping the mask too long on the face. If the signs of anæsthesia are not developed in 30 or 40 seconds, too much air has been allowed, or too small a dose has been given. When food has been taken a short time previous to the administration of the anæsthetic, pallor is likely to occur, followed by vomiting into the mask. Several cases have been eported in which severe collapse occurred, lasting for some hours and causing alarm. Mr. W. Foster Cross * mentions two cases in which marked general rigidity, opisthotonus, and spasm of the jaw muscles developed. And Dr. Swan † cites two instances

* *Proc. Soc. Anæsth.*, vol. vi. p. 45. † *Ibid.*

of collapse, one in his own and one in the practice of Dr. Rolland. In both these cases anæsthesia had been prolonged by somnoform for twenty minutes. Excitement and struggling are occasionally met with. As Dr. Kirkpatrick * indicates, micturition is common if the bladder is not emptied before the administration, so this precaution should not be omitted. I have met with cases of excitement, but none of serious danger. Fatalities have occurred, however, during the use of somnoform ; and when we bear in mind that Cole's experiments show conclusively that the physiological actions of somnoform and ethyl bromide are almost identical, it follows that the dangers of somnoform must be almost the same as those of ethyl bromide ; and with these we must reckon. Somnoform readily decomposes ; if any free bromine is present, the colour becomes yellow and the anæsthetic is unfit for inhalation. As a rule, the last portion in the bottle gives unsatisfactory results, especially if the bottle has been open for a day or two, and then should not be used.

Ethyloform is a mixture of ethyl bromide, ethyl chloride, and methyl chloride, and would appear to be more dangerous than somnoform, and so had better be avoided.

Narcotile, † kelene, anesthyle, and other anæsthetics which are sold under similar names are too uncertain in composition to require more than a passing notice. They are administered in the same way as ethyl chloride.

Recently the presence of ethyl chloride in certain brands of chloroform has been noticed, and it is claimed that the more volatile agent renders the inhalation more rapid and more generally satisfactory. However, unless ethyl chloride is added in appreciable quantity—such, for example, as 3 per cent. or more—it is at least difficult to understand how its presence in chloroform can exert any marked action during the induction period.‡ We do not as yet possess sufficient evidence to come to any satisfactory conclusion as to the advantage of adding ethyl chloride to chloroform. It is certain, however, that the mixture is more volatile than chloroform, and that during evaporation the composition of the mixture remains practically unaltered.

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* *Med. Press and Circ.*, April 22, 1903.

† Dr. Tom Eastham, *Lancet*, April 18, 1903, p. 1091, gives his experience of narcotile, which he terms " bichloride of methyl ethylene."

‡ See Dr. Wade's paper in *Trans. Soc. Anæsth.*, vol. vii. p. 84.

Uses of Ethyl Chloride and its Mixtures.

For brief operations such as those of dentistry, the removal of tonsils and post-nasal adenoid growths, the opening of abscesses, and generally for occasions when nitrous oxide is commonly employed, ethyl chloride is useful. For brief operations upon infants and children under six years of age it is one of the best anæsthetics we possess, being more readily taken than ether when that agent is given by itself, easier to manage than nitrous oxide for very young children, and perhaps safer than chloroform. It is also a valuable means of introducing ether narcosis, and especially is this so in the case of nervous persons. Its use has been extolled in the operations of ophthalmology, and for those of the rhinologist, aurist, and laryngologist, when the time required by the surgeon is not more than two or three minutes. In the case of operations upon the eye, when after-vomiting is dangerous, ethyl chloride is not an ideal anæsthetic unless possibly when given by an open method.

For more prolonged operations upon the mouth and upper air-passages, ethyl chloride as usually administered is inconvenient, since the surgeon is obliged to interrupt his work while the mask is reimposed and more anæsthetic is given. Dr. Barton * has obviated this by an apparatus which enables the anæsthetist to give the vapour of ethyl chloride continuously (see figs. 76 and 77). For this purpose the vapour is carried by a tube either through the nostril or to a delivery-tube attached to a gag. The supply of vapour is maintained by the use of a specially constructed cylinder holding 250 grammes of ethyl chloride, which is controlled by taps. The vapour is warmed by hot water.

A few words may be said as to the comparative merits of nitrous oxide gas and ethyl chloride, since these anæsthetics are used in similar cases.

Ethyl chloride is more portable ; it does not produce cyanosis unless given for too long a time and with undue air limitation, and it ensures a deep and quiet period of anæsthesia, which is considerably longer than that obtained by the inhalation of nitrous oxide. On the other hand, it is certainly less safe, and is more liable to produce after-nausea and vomiting. In dental

* "A Guide to the Administration of Ethyl Chloride," p. 21, H. K. Lewis, London.

surgery I think ethyl chloride should not replace nitrous oxide as a routine anæsthetic, but may be adopted instead of the gas

FIG. 76.—Dr. Barton's apparatus for administering ethyl chloride for prolonged operations on the mouth or nose.   Induction about to commence.

FIG. 77.—Anæsthetic being maintained by means of a tube.

ether sequence, for cases of numerous or difficult extractions, e.g. of lower wisdom-teeth. For cases of multiple extractions in the upper jaw in persons with a short upper lip who are less

easily kept anæsthetic by a continuous gas method, ethyl chloride is useful. For the removal of tonsils and growths in children, more especially in hospital practice, ethyl chloride is better than nitrous oxide ; the former is, indeed, considered by some as almost an ideal anæsthetic in these cases. Patients who are inclined to become cyanosed when inhaling nitrous oxide, and those who '' come round '' very quickly, also those who are restless and excited under that agent, usually respond well to ethyl chloride.

ETHYL BROMIDE (HYDROBROMIC ETHER).

Ethyl bromide, $C_2H_5Br.$, is prepared by the action of phosphorus tribromide on alcohol. It was discovered by Serullas in 1827 and introduced as an anæsthetic by Mr. Nunneley of Leeds in 1849. It occurs as a clear, colourless, heavy, strongly refracting, neutral liquid, with a pleasant ethereal odour. Boiling-point, 39° C. ; specific gravity, 1·455.

It is soluble in water (about 1 in 100), and is freely soluble in ether and alcohol.

It is decomposed by exposure to air and sunlight, and should be stored in well-closed bottles in a dark place.

The principal tests are as follows :—

Residue.—10 c.c. evaporated in a shallow glass vessel on a water bath should leave no visible residue.

Free acid, bromine and bromides.—When 5 c.c. of ethyl bromide are shaken with 5 c.c. of distilled water, the upper aqueous layer should not redden blue litmus paper, nor should it yield any turbidity on the addition of silver nitrate solution.

Ethyl bromide undergoes decomposition when exposed to air or light, with the liberation of free bromine, and becomes irrespirable. This impurity gives it a yellow colour, a circumstance which should warn against the use of impure samples.

Physiological action.*—Rabuteau, in 1876, carefully in-

* The late Sir B. W. Richardson wrote (*Asclepiad*, 1885) favourably of its claims, and urged that pure samples were free from the dangers which arise with the commercial bromide. The bibliography of '' bromethyl '' has become very large ; important papers have been written by Hartmann and Bourbon (*Rev. de Chirurg.*, No. 9, 1893, p. 701), Dastre ('' Des anesthétiques,'' p. 189, Paris, 1890), Lewis (*Medical Review*, New York, March, 1880, p. 342), Turnbull of Philadelphia, Chisholm, and Silk (*Practitioner*, May 1891), among many others. A useful list of authorities

vestigated the subject.* In human beings ethyl bromide produces unconsciousness and anæsthesia in one minute, and complete muscular relaxation in two or three minutes. Schneider speaks of two periods : in the initial one sensibility is lessened without loss of consciousness or interference with respiration and circulation ; in the second there is complete loss of consciousness, occasionally with convulsive seizures. Larger doses produce profound narcosis, cyanosis, muscular relaxation, loss of pupillary reflex, and gradual failure of respiration and circulation. The heart beats for an appreciable time after breathing has ceased. Elimination takes place by the lungs. No suffocation or laryngeal irritation appears to exist, although there is much congestion of the head and neck with lacrimation, and an increased secretion of mucus, which last may give trouble.

When ordinary doses are given to produce anæsthesia, the following phenomena occur : the breathing is quickened, the pulse accelerated, and the heart's action somewhat weakened. The pupils dilate. The return to consciousness after withdrawal of this anæsthetic is very rapid. Vomiting is said to occur frequently during the administration, and even to continue for some hours. Blood-pressure, according to Dr. H. C. Wood, is slightly reduced by small, and very considerably by large, doses of this agent.

Deaths from ethyl bromide are due, according to Wolff and Lee, to cardiac failure ; but these statements are denied by some observers. Ott, on the other hand, believes that ethyl bromide kills by its direct action upon the respiratory centre, and does so whether it is injected intravenously or is inhaled. The heart-failure, he thinks, is secondary to the interference with respiration. According to Ginsburg, this fall of blood-pressure is due to paralysis of the vaso-motor centres, the vagus centres being unaffected. The action of this agent upon the heart is probably similar to that of chloroform (H. C. Wood). Tcherbacheff corroborates Wood's results, and asserts that death is caused by cardiac paralysis and pulmonary œdema. Cole was unable to detect any effect on the vaso-motor system ; he agrees with Wood and others in believing that respiration is

will also be found in the valuable chapter on " bromethyl " in Terrier and Péraire's book (" Petit Manuel d'Anesthésie Chirurgicale," Paris, 1894, p. 154), to which the reader is referred for greater detail upon the subject.

* *Comptes rendus de la Soc. de Biol.*, t. xxxiii. p. 1294.

affected by the action of ethyl bromide upon the respiratory centre.

Method of administration.—In giving ethyl bromide, air is usually entirely excluded. Turnbull, however, allows some air at the commencement of the inhalation. An Ormsby's inhaler or an Allis's apparatus answers very well. When an Ormsby's inhaler is used, a drachm or a drachm and a half is poured upon the sponge, air being excluded until consciousnesss is lost (Silk). Anæsthesia is recognised by snoring and loss of conjunctival reflex. This usually occurs in half a minute to a minute, and at this point the inhalation must be stopped. Although it is asserted by some observers that there is little struggling, violent movements certainly take place in some instances. Owing to the great rapidity with which consciousness returns (1 to 3 minutes), careful attention is needed in order that the anæsthetist may maintain narcosis. The respiration and pulse require watching throughout the administration. No prolonged operation should be attempted under ethyl bromide, even when it is given intermittently : authorities agree that the inhalation should not be continued beyond forty minutes. It is, however, best adapted for quite short operations.

Hartmann and Bourbon adopt the following method : 10 c.c. to 15 c.c. (2–4 drachms) are placed on a compress, and as soon as the patient grows used to the odour the compress is placed tightly over the mouth and nose. If any struggling occurs, the patient is held in the recumbent posture for a few seconds, when he becomes quiet. Anæsthesia supervenes after a dozen breaths. Inhalation must now cease, or sever muscular convulsions become developed. When an operation cannot be completed in about one to two minutes, one or two inhalations of the concentrated vapour are given ; then air is admitted, to be followed, if necessary, by further inhalations of the anæsthetic. It seems, however, wiser to give only one dose, and to follow it by ether. One to two drachms is a safer dose.

Terrier adopts the following method : A few drops are used at a time, all air being excluded, and more ethyl bromide is added guttatim when the last dose has evaporated. When air-exclusion is not practised, this anæsthetic can be exhibited from a Skinner's or other mask. In this plan a considerable quantity of the anæsthetic is used. Turnbull, who was one of the first to employ ethyl bromide and to study its action, uses a towel

folded into a cone. He pours into the cone 75 to 150 drops in the case of an adult, and 50 to 100 in that of a child. Kocher of Berne, according to Dr. Huggard,* employs this agent before ether. He suggests 15 to 30 c.c. (4 to 8 drachms) at a time as one dose. These are certainly far from safe doses. As soon as the signs of narcosis appear ether is substituted. Very weak or anæmic people and young children are considered by Kocher to be bad subjects for this method. Alcoholism and Bright's disease are contra-indications to its use.

Cases suitable for ethyl bromide.—At the present time few persons employ this anæsthetic. If used at all it should be restricted to brief operations, *e.g.* in dentistry, but it seems unwise to adopt so potent a drug for this class of operations. Turnbull has employed it in midwifery.

Dangers resulting from the use of ethyl bromide.—Eight deaths at least are stated to have resulted from its administration, but some of these were in reality due to impurities contained in the sample used. Deaths have occurred, however, even when the pure drug has been used ; so I am disposed to agree with Professor Wood,† who regards this agent as equally dangerous with chloroform. Cases of death due to inhalation of ethyl bromide have been recorded in which visceral degenerations were noted (Reich and Flatten). A. B. Kelly, ‡ who has used this agent extensively, had thirty samples examined, and 60 per cent. were found to be unfit for anæsthetic purposes. The importance of obtaining absolutely pure specimens cannot be over-estimated.

Pental.—Trimethylethylene was described by Von Mering as an anæsthetic in 1887, and has been widely used in Germany for brief operations. Amylene, an agent which was employed with some success by Snow in 1856, agrees in many of its physical and chemical properties with pental. Amylene is not now used.

Administration.—Pental is given with the same precautions as in the case of chloroform. Holländer § employed Junker's inhaler in its exhibition. Mr. Constant, of Scarborough, has used pental in dental surgery, exhibiting it from a Clover's regulating ether inhaler. Dr. Stallard, of Manchester, has used

* *Lancet*, Sept 12, 1903, p. 745.
† *Therapeutics*, 1905, p. 102.
‡ *Brit. Med. Jour.*, Aug. 30, 1902.
§ Holländer's " Pentalnarkosen, 1893," in *Deutsch. Med. Woch.*, No. 33, contains much information on pental, and should be referred to for further details.

pental in 150 cases ; he also adopts Clover's inhaler, pouring in two drachms and excluding all air until unconsciousness is obtained. The lid reflex was only lost in deep narcosis. The breathing under pental becomes almost imperceptible ; cyanosis and stertor are rare. The induction period is about 57 seconds, and the anæsthesia lasts 76 seconds.

After-effects. — Muscular contractions, enfeeblement of the heart-action, and respiratory spasm were noted. Dr. Stallard has met with one fatal case. The dangers of pental are summarised by this observer : (1) Its insidious action renders it very difficult to avoid giving an overdose ; (2) tendency to make the patient scream ; (3) tendency to respiratory failure ; (4) it causes cardiac failure. Breuer (Vienna) had one threatened death from respiratory failure in 120 cases. He found the anæsthesia too slight for the reduction of dislocations. Both Schede * (Hamburg) and Sick † have noted casualties under pental. According to Kleindeinst, albuminuria, hæmaturia, and hæmoglobinuria may follow its inhalation. Cerna found a marked fall of arterial pressure ensued upon its inhalation, while Gurlt's statistics gave pental a death-rate of three fatalities in 600 narcoses. In spite of these alarming statements, we find Philip,‡ from his experience in the Kaiser Friedrich Children's Hospital, Berlin, strongly in favour of pental. He met with no serious after-effects.

The advantages claimed for pental over other anæsthetics appear to be more than counterbalanced by its dangers, which seem to depend upon the drug itself, and not upon any faulty method employed. At best it is only of use in short operations, and solely when a superficial narcosis is required.

A very large number of chemical compounds have been employed as general anæsthetics, but as they possess no advantages over those in common use no special mention is made of them. The Glasgow Committee of the British Medical Association investigated many of these, so those who are interested in the matter can refer to the *British Medical Journal* in which the Committee's Report appears. Dr. Gwathmey § has devoted 150 pages to the subject and gives a comprehensive account of both anæsthetics and analgesics, appending a useful bibliography.

* "Congress der deutsch. Gesellschaft f. Chir. zu Berlin," *Berlin. klinische Woch.*, Aug. 1, 1892, p. 784.

† *Deutsch. Med. Woch.*, No 20, 1893, p. 485, and No. 22, p. 538.

‡ *Zeitsch. f. Kinderheilk.*, bd. iii., iv. 1893.

§ *Anæsthesia*, chap. xx. p. 688.

CHAPTER VII.

ALKALOIDAL DRUGS WITH GENERAL OR LOCAL ANALGESICS : ANÆSTHETIC MIXTURES, SUCCESSIONS, AND SOLUTIONS ; ANOCI-ASSOCIATION.

I. The Employment of Alkaloidal Drugs Antecedently to General or Spinal Anæsthesia or Local Analgesia.

The systematic employment of alkaloids in association with general and local anæsthesia subserves certain purposes : (1) The patient is soothed if not completely put to sleep before having a general anæsthetic, a local or spinal analgesic, administered ; and so is spared the distress often felt by nervous persons ; (2) the amount of the general anæsthetic required is diminished ; (3) many of the undesirable effects incidental to general anæsthesia are prevented, *e.g.* the salivation and bronchorrhœa caused by ether do not arise if atropine has been previously injected ; (4) psychic shock, which, according to Dr. Crile, acts so prejudicially upon the central nervous system, is lessened or abrogated.

The attempt to obtain complete anæsthesia by alkaloids has not been found wholly successful in general surgery unless used in association with general or local anæsthetics. Gauss's " Twilight Sleep " method is described in Chapter IX.

The experience of the last thirty years has confirmed that of Schneiderlin, who availing himself of the discovery of scopolamine by Schmidt (1890), showed that the three drugs, scopolamine, morphine, and atropine,* when used together, give a better result than when they are given in other combination. They appear to supplement one another's actions, in some directions

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* See a clinical lecture by the present writer, *Clinical Journ.*, June 14, 1911, p. 145, for further information. Dr. W. Webster (*Bio-Chem. Journ.*, vol. iii. No. 3) describes a series of experiments with these alkaloids. His views differ in some respects from those expressed in the above account, but the conditions of his experiments are not quite parallel to those obtaining in clinical work.

acting synergistically, but antagonising each other in others, thus protecting the patient from deleterious consequences. This is brought out in studying the development of the use of some alkaloids. Thus Nussbaum, of Munich, suggested the use of **chloroform** and **morphine** as early as 1863 ; Claude Bernard also studied this combination ; while MM. Guyon and Labbé, employing gr. $\frac{1}{6}$ to gr. $\frac{1}{2}$ of morphine, applied this method in surgery. Although Kappeler stated that the heart is protected by the use of morphine, the consensus of opinion is opposed to this view, and there is no doubt, as Dastre has pointed out, that it depresses the respiratory centre. Sir Victor Horsley has shown that the danger of respiratory collapse is increased when morphine is employed for patients whose respiratory centres are affected by disease. Poncet, from his experience in the Franco-Prussian War, came to the conclusion that this combination is dangerous both on account of the prolonged stupor it engenders, and because it causes a lowering of body temperature. Demarquay's experiments on animals also support this view. Further, according to Regnier, the elimination of chloroform is delayed by the preliminary injection of morphine.

It is, however, highly probable that many of the dangers attributed to this method are in fact the result of a failure to recognise that when morphine has been used, even in small doses, the quantity of chloroform subsequently given must be materially lessened. If this is not done the cumulative effect of these two powerful drugs upon the respiratory centre will undoubtedly predispose to collapse and death from asphyxia. To counteract some of these dangers, Dastre, Morat, Aubert (Lyons), and others introduced the plan of using a **morphine** and **atropine** injection antecedently to chloroform. The method of giving morphine gr. $\frac{1}{6}$ and atropine gr. $\frac{1}{150}$ to gr. $\frac{1}{100}$ has been widely employed, and many anæsthetists still adopt it. The drugs should be injected one hour before the general anæsthetic is introduced. Dr. McCardie, however, thinks that the injection should be made three to four hours before the operation in order that the full morphine effect may be present at the commencement, and be practically exhausted before the operation is completed. I find that many persons make the injection half an hour before giving the general anæsthetic, but I believe this to be a mistake which stultifies the procedure.

When no somnifacient effect is desired **atropine** in doses of

gr. $\frac{1}{150}$ to gr. $\frac{1}{100}$ may be employed to exert its antagonising influence. Thus Sir E. Sharpey Schäfer has demonstrated that this alkaloid lessens **vagal activity,** and he recommends its employment to prevent the danger of **vagal inhibition** of the heart when chloroform is inhaled. He suggests that as much as gr. $\frac{1}{50}$ may be used in suitable cases, but it must be remembered that atropine when given alone often causes a disagreeable dryness of the mouth and throat, and this may persist for some hours.

The various objections to morphine which have been noted above are due, it is believed by some observers, to the impurity of the drug, or at least to the differences of strength which exist in the drugs employed. Dr. Sahli, of Berne, believing that it is possible to obtain standardised solutions of the chlorides of opium, has combined, under the trade-name of **Omnopon,*** a mixture of the chlorides of the following : morphine, narcotine, codeine, papaverine, narceine, thebaine, hydrocotarnine, codamine, laudanine, laudanidine, laudanosine, meconidine, papaveramine, protopine, lanthopine, cryptopine, gnoscopine, oxynarcotine, xanthaline, and tritopine. Omnopon is an amorphous yellow-brown powder, soluble in water, stable and with a slight acid reaction. One gramme of Omnopon equals five grammes of 10 per cent. opium, but this estimate Dr. Leipoldt regards as too low. The same authority states that it is safer than the scopolamorphine (scopolamine and morphine) injection, producing less excitement and greater quietude. The dose is 1 c.c. of a 2 per cent. solution ; this is injected one hour before the operation, although dividing the dose and giving two or three injections at $1\frac{1}{2}$, 1, and $\frac{1}{2}$ hour before the inhalation he thinks produces a better result. It may be combined with atropine and possibly with scopolamine. A similar preparation is supplied by Messrs. Allen and Hanburys, under the name of Alopon. It is a brown powder, soluble in water five times the strength of opium, so that gr. $\frac{1}{5}$ Alopon equals one grain of opium or ten minims of the tincture of opium.

TECHNIQUE IN THE USE OF SCOPOLAMINE, MORPHINE (OMNOPON), AND ATROPINE.

It is to be remembered that the ordinary rules guiding the clinical use of morphine, atropine and scopolamine must be

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* See a careful review of this subject by Dr. C. L. Leipoldt, F.R.C.S., entitled " Some Remarks on Omnopon Anæsthesia," *Lancet*, Feb. 11, 1911.

followed in this method, with the reservation, however, that the respiratory mechanism is less affected when all the three drugs are used together than if morphine and atropine alone are introduced.   It is sometimes urged that, since scopolamine and atropine possess certain properties in common, there is no advantage in employing the former.   This is, however, a mistake, for scopolamine acts not only as one of the atropine group, but also as a good somnifacient, and my experience, which is now an extensive one, convinces me that better results follow the use of the combination of all three drugs.   It is also advanced as an objection to the method that the post-operative sleep is very profound and very prolonged.   This is so, after long and exhausting operations, but therein lies one of the greatest advantages of the method.   It is true that the patient needs closer watching for some hours during his recovery than when only a general anæsthetic is used.   This, although possibly an objection in large general hospitals which are understaffed with nurses, should not weigh in private practice.   It is essential that chin drop should be looked for and at once corrected, and that the posture of the patient should be carefully arranged so that no postural interference with respiration, however slight, can arise. The nurse must, of course, be warned upon these points.   Again, since the drugging of the patient is already tolerably deep, the amount of the general anæsthetic given to him, after induction is complete, should be extremely small.   Assuming that these preliminary considerations have received due attention we may indicate the appropriate procedure.   This applies to all cases when a general anæsthetic is to be given either by inhalation, intratracheal insufflation, intravenous infusion, colonic absorption, or a local infiltration, a regional, or a spinal anæsthesia is to be practised.

If **hedonal** or **isopral** infusion is contemplated the preliminary injection should **not** be given.

The patient must be placed upon a wheeling trolley in his own room well covered up, and a hypodermic injection of the following solution—scopolamine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{6}$, or an equivalent dose of Omnopon,* and atropine gr. $\frac{1}{100}$—should be given into a sterilised area of his arm.   It is best to keep the preparation in ampoules which are sterilised and sealed.   An

* Supplied by the firm of Hoffermann, La Roche, who supply it in sterilised ampoules.

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ampoule is broken and the fluid taken into the syringe, but care must be used that only five minims—the amount of fluid holding the doses indicated above—is drawn into the syringe. It is not safe to assume that any one ampoule contains only this amount. The dose may be given one hour or one hour and a half; or in two divided doses, one two hours, the other one hour; before the operation. In the case of very vigorous males more than gr. $\frac{1}{6}$ of morphine may be required, and if this is so it is better to divide the dose, giving first morphine and subsequently the three drugs. As delicate persons and children may require a smaller dose, such variations in dosage should be decided in each case on general grounds. It is unwise to increase the dose of scopalamine given. *After the injection the patient should be kept absolutely quiet*, no talking or movement must be allowed, and the room must be darkened. If ether is to be employed, it is better to give a few whiffs of chloroform to deepen the " dawning sleep " before ether is administered, as its pungent smell arouses the patient. Personally, I do this with a Vernon Harcourt inhaler. On no account must the patient be allowed to walk to the operating-room—indeed, it is best to anæsthetise him in his own room and then wheel the trolley into the operating-room and carefully slide him on to the operating-table from the trolley.

Subsequently the anæsthesia is pursued along normal lines provided the caution given above is not lost sight of, *i.e.* that the patient will need **extremely little of any anæsthetic** to maintain unconsciousness. It is quite a common occurrence for the patient to move a leg when the first skin incision is made, but he does not repeat this. The breathing is usually slow and the lung ventilation slight, so that the induction period is sometimes rather prolonged. The signs of anæsthesia are somewhat masked. The ocular phenomena are not reliable, as the pupillary reaction is altered by the drugs, and conjunctival reflex is lessened in the same way, but is seldom absent, nor should it be during the operation. As has been stated above, the period of recovery is long and the patient requires watching. The after-effects, sickness, headache, etc., are materially lessened.

Some surgeons consider that muscular rigidity is increased by the use of scopolamine, but this, I think, is not the case. If the abdominal muscles are stiff it is usually due to ineffectual breathing and the associated signs of slight asphyxia, of which muscular rigidity is one.

When **ether** is to be given alone, even if morphine and scopol-amine are not used, the injection of **atropine should never be omitted**. It prevents excessive secretion of mucus and of saliva, and so removes the most potent cause of after-sickness, and post-anæsthetic lung complications. Although one hour is the best interval of time which should elapse between the hypodermic injection and the giving of the anæsthetic, yet if for any reason this arrangement is impossible, the injection may be given later ; especially is this so in the case of atropine.

If scopolamorphine or morphine alone is injected not long before the use of the anæsthetic the anæsthetist must be pre-pared for a gradually increasing opium effect, which will probably be at its height at the time that the operation is completed.

Comparing the post-operative condition of patients treated in the above way with those who have not had the hypodermic medication, that of the former class is undeniably better than that of the latter.

If there is any necessity for a speedy induction the routine system mentioned above of nitrous oxide—ether (by closed method), followed by open ether or chloroform, lends itself admirably for the anæsthesia subsequent to the hypodermic injection.

II. Anæsthetic Mixtures, Successions, and Solutions.

The rationale of using mixtures involves two principles. The one is that in these mixtures chloroform is diluted. It is assumed that the constituents of a mixture evaporate in a definite pro-portion to their strength in it. If A, B, C, were a mixture such that one part of A were combined with two parts of B and three of C, it is assumed that volumes of the vapours of A, B, and C would be represented by the proportions of 1, 2, and 3. How-ever, as the sequel will indicate, this theoretical statement is not borne out by experimental and clinical observation. The other principle involved is that it is possible by combining two or more anæsthetics in a mixture to induce mutual antagonism in certain directions, thus producing a resultant action which protects the patient from the deleterious effects of the individual constituents of the mixture. After the acceptance in France and throughout Europe of Bert's pronouncement that the

anger of chloroform is merely a question of the concentration of the vapour inhaled, a number of methods were suggested with the object of obtaining a dosimetric system of giving chloroform, and among these were various mixtures schemed with the view of keeping the chloroform constituent below 2 per cent.

Mixtures and Sequences.

These are of two classes : (1) Combinations of the alcohol or ethereal series ; (2) Alcoholic or other anæsthetics used in conjunction with narcotics or analgesics.

The best known and most useful of the first class are :—

The A.C.E. MIXTURE.—Composed of 1 part absolute alcohol, 2 parts chloroform, and 3 parts·of ether, all by volume.

The C.E. MIXTURE.—Composed of 2 parts by volume of chloroform, and 3 parts by volume ether.

BILLROTH'S MIXTURE.—3 parts by volume of chloroform, 1 part by volume each of absolute alcohol and ether.

The VIENNA MIXTURE.—1 part by weight of chloroform to 3 parts by weight of ether.   Richardson * gives the formula for this mixture as 8 parts of ether to 1 of chloroform in hot weather, and 6 parts of ether to 2 of chloroform in cold.

The MIXTURE recommended by Linhart contains 1 part by weight of absolute alcohol, 4 parts by weight of chloroform.

Sir E. Sharpey Schäfer advocates a mixture of 1 part by volume of absolute alcohol and 9 parts by volume of chloroform (the C.A. mixture).

" METHYLENE."—Methylic alcohol 30 per cent. and 70 per cent. chloroform by weight (Regnauld and Villejean).

SCHLEICH'S SOLUTIONS consist of chloroform, sulphuric ether, and petroleum ether (see below).

The **A.C.E. mixture** was suggested by Dr. George Harley, and strongly recommended by the Anæsthetics Committee of the Royal Medical and Chirurgical Society of London.   They speak of its action as midway between that of chloroform and ether.   It is made by mixing one fluid ounce of absolute alcohol sp. gr. 0·795 with two fluid ounces of chloroform sp. gr. 1·497 and three fluid ounces of ether sp. gr. 0·720.   It has been largely used in England, and, although not without objection, is a good substitute in many cases when ether cannot be taken.   The main

* *Asclepiad,* 1885, p. 274.

drawback to the employment of this and all other mixtures is that the agents employed in their formation do not evaporate in the ratio in which the fluids are mixed, and hence it is impossible to be quite sure what percentage vapour of chloroform is being inhaled. The liability to this irregular evaporation may be minimised by evaporating one drachm or a half-drachm of the mixture at a time. Ellis * has proposed to blend the vapours of alcohol, chloroform, and ether in a specially constructed apparatus, with the view of obtaining a combination of vapours of the constituents corresponding with the proportion in which the fluids are blended. Dr. Gwathmey † has revived Ellis's suggestion and has devised a practical apparatus. This consists of three six-ounce bottles, in each of which are four tubes varying in length from one which reaches the bottom of the bottle to one which only perforates the stopper. These tubes are assumed to represent four vapour strengths. Air or oxygen is forced through these tubes by means of a hand-pressure ball—as in Junker's apparatus—and the amount is assumed to be determined by the degree of compressure exercised. Dr. Gwathmey's most recent apparatus obviates some of the sources of error common to such inhalers. A somewhat similar idea is carried out by Tyrrell's double-bottle method, although the amount of each anæsthetic given is wholly controlled by the administrator.

Tyrrell's ‡ apparatus is shown in Fig. 78. Two Junker's bottles are connected, the tubes being so arranged that the administrator can give as much of each vapour as he decides is required for the case. One pair of bellows controls the two bottles, a Y-shaped piece with a little graduated tap on each bifurcation of the Y being inserted between, while a similar Y-shaped piece allows the passage of the vapour from each bottle to a single tube which is attached to the face-piece. Before commencing the inhalation the tap controlling the ether supply is adjusted so that only so much ether will escape as can be respired easily. In the case of a child less ether is allowed to pass. This tap is left in this position, but the tap on the bottle cutting off the ether is closed, and only opened if in the course of the administration of the chloroform, conducted on ordinary principles, ether is required. The same end has been obtained by various apparatus

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* *Med. Times and Gaz.*, 1870, vol. ii. p. 107.
† *Med. Record* (New York), Oct. 14, 1905.
‡ *Trans. Soc. Anæsth.*, vol. i. p. 1, 1898.

which, although possessing merit, cannot be described in this place.

Method of employment of the A.C.E. Mixture.—This anæsthetic mixture may be given in a Rendle's mask, a cone, or by the open method. When a cone or Rendle's mask is used, a drachm of the mixture is poured into the mask, and fresh quantities added when the first has evaporated. I find Allis's inhaler also answers well (see Fig. 33). Junker's inhaler,

FIG. 78.—Tyrrell's method of combining the vapours of chloroform and ether.

fitted with the flannel mask, is very convenient for giving the A.C.E. mixture to children. It can also be used by the open method, and is then dropped upon a mask or corner of a towel, but the induction by this plan is tedious. Although this solution is sometimes given from a " Clover's " inhaler, the bag having been taken off, the method is, I think, not free from danger even if the inhaler is constantly lifted from the face and air very freely admitted.* The fact that chloroform is present in the mixture

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* See a valuable paper by Dr. Edgar Truman, *Lancet*, Feb. 16, 1895, p. 403, and a further one on the same subject by Sir William Ramsay, F.R.S., *Transactions of Society of Anæsthetists*, vol. ii. p. 13, in which it is pointed out that this mixture, given from a closed inhaler, is unsafe on account of the irregular manner in which the constituent parts are given off, even when the bag is removed, owing to the respective densities of the vapours ; the chloroform falls towards the patient while the ether evaporates into the room.

makes it obligatory that plenty of air should be admitted. Both respiration and pulse must be carefully noted, as fainting and asphyxial troubles may occur during the employment of this mixture. The signs of anæsthesia are those described when dealing with chloroform. Duskiness is common and is due to insufficient air. Stertor should never be permitted. Patients who will not tolerate ether often take this mixture well.

After-effects are much the same as those of chloroform or ether, and are commonly slight. Deaths have occurred during the use of the A.C.E. mixture, and have been attributed either to respiratory or cardiac failure. Physiologically the A.C.E. solution resembles chloroform antagonised to some extent by the alcohol it contains. This antagonism reveals itself in the maintenance of the height of blood-pressure, and in keeping the respirations at a force and frequency very little below the normal.

The **C.E. mixture** is simply the A.C.E. solution with the omission of the alcohol. In the Report of the Royal Medico-Chirurgical Society issued in 1864, three mixtures are given : (A) the A.C.E. (George Harley), (B) chloroform 1 part and ether 4 parts by volume, and (C) chloroform 1 part and ether 2 parts by volume. (B) and (C) are there stated to have been used extensively in America (*sic*). The action of (B) is said to resemble that of ether, and this is true during the earlier part of the administration, since the ether evaporates more rapidly than does the chloroform ; later the chloroform effect predominates. The C.E. mixture is in common use, and is prepared by mixing 2 parts of chloroform (by volume) with 3 parts of ether (by volume). It is employed in the same way as the A.C.E., over which it possesses no advantage.

The research of Schäfer and Shirley * shows conclusively that the C.E. mixture is based upon a wholly fallacious theory that the alcohol in the A.C.E. mixture is merely a menstruum, and the ether in the C.E. mixture exerts a stimulant action upon the circulation, and so counteracts the depressant effect of the chloroform contained in the mixture. They prove that the C.E. mixture acts precisely like chloroform of similar strength, that the ether exercises no independent action—is, in fact, a mere diluent. Nor is this all. They found, further, that the A.C.E. mixture owed its undoubted merit wholly and solely to its alcohol (16·5 per cent.), while its ether was, as far as blood-pres-

* *Trans. Roy. Soc. Edin.*, vol. xli. part ii. No. 12.

sure is concerned, a negligible quantity. The proportion of 10 parts by volume of absolute alcohol to 90 parts by volume of chloroform in their experience gave better results than did the larger amounts of alcohol. In fine, their results indicate that the C.E. mixture is more dangerous than the A.C.E., is about upon a level with diluted chloroform, and when employed without complete admixture with air is to be avoided ; that the A.C.E. mixture possesses no advantage over the alcohol-chloroform mixture C.A. (1 in 10), and should be replaced by it. These remarks apply with equal force to **Richardson's mixture** (alcohol 2, chloroform 2, and ether 3 parts) and the **Vienna mixture** (chloroform 1, ether 3 parts).

Billroth's mixture (alcohol 1, ether 1, chloroform 3 parts) may be considered as an alcohol-chloroform mixture of 20 per cent. alcohol, and this, as has been shown above, possesses no advantages over the alcohol-chloroform mixture (1 in 10). If used at all it must be given in the same way as diluted chloroform, and with the same precautions.

The Roth Dräger Chloroform and Ether Apparatus.

This is one of the best systems in that it supplies the anæsthetist with a ready means of giving either chloroform or ether or a combination of these in definite doses and in association with oxygen.

Oxygen under pressure is passed into a bag, taking up the vapour of chloroform and ether as the latter is to be used. These anæsthetics drop at definite rates controlled by a simple mechanism. The pressure of oxygen and the rate of dropping of the anæsthetics per minute are registered on dials. The mixed vapours and oxygen enter a special type of metal valved face-piece, which is supplied with an air slot admitting the required proportion of air. The actual percentage vapour is readily estimated, and the strength used is under the control of the anæsthetist. I have used the apparatus and found it quite reliable. The only objection to it for general use is that higher percentages of $CHCl_3$ vapour than 2 are easily obtained, and this fact probably accounts for the fatalities which have occurred during its use.

Alcohol-chloroform mixtures.—This, which as stated above is a 1 in 10 mixture, is administered in the same way as pure chloro-

form, and with the same precautions. This mixture is conveniently termed the " A.C." mixture.

Linhart's mixture (20 per cent. alcohol) is employed similarly. It contains more alcohol than is necessary, and gives less good results than the 10 per cent. mixture.

Methylene, or " bichloride of methylene," is stated by Regnauld and Villejean to be merely a mixture of methylic alcohol (30 per cent.) and chloroform (70 per cent.). It is seldom used at the present time. It may be given from a Junker's inhaler. Several deaths have occurred during its use.

Schleich's solutions for general anæsthesia.*—The rationale of these solutions lies in the assumption that the rapidity with which anæsthesia can be obtained and the permanence of the anæsthesia depend upon the boiling-point, or temperature of maximum evaporation of the agent which is inhaled. It is suggested that by altering the temperature of maximum evaporation, so as to make it nearly coincide with the blood heat, it will be possible to regulate the intake and elimination of the anæsthetic vapour in such a manner as to maintain anæsthesia without over-narcotism, since the elimination under such conditions would prevent accumulation of the anæsthetic in the blood. Schleich proposed three solutions : No. 1 for short operations, Nos. 2 and 3 for major operations. These are :—

	No. 1.	No 2.	No 3.
Chloroform	45 parts.	45 parts.	30 parts.
Ether (sulphuric)	180 ,,	150 ,,	80 ,,
Ether (petroleum)	15 ,,	15 ,,	15 ,,
Boiling-point	38° C.	40° C.	42° C.

The petroleum ether employed must have a boiling-point between 60° and 65° C., and a specific gravity between 0·670 and 0·700, since the common commercial kind induces deleterious effects when inhaled for any time. Willie Meyer † (New York)

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* See *Schmerlose Operationen*, II. Aufl., Berlin, 1897.

† See *J. Am. Med. Assn.*, Feb. 28, 1903, *Med. Rec.* (New York), Aug. 15, 1908, for full particulars of the work of Weidig and Meyer, who modified Schleich's solutions by adding ethyl chloride. This combination was called Anæsthol, and was adopted by Schleich, who, however, omitted the petroleum ether, substituting ethyl chloride. Meltzer (*New York Med. Record,* 1898, p. 607, and 1908, Aug. 18) proved that petroleum ether possesses no anæsthetic effects, and if used in large quantity paralyses respiration.

and Maduro (New York) have studied the solutions, and were favourably impressed by them, but their experience does not seem to have been corroborated by other workers.

According to Rodman,* the induction of anæsthesia took from fifteen to twenty minutes. The solution, although causing some excitement, compared favourably with ether in this respect, and also produced more complete muscular relaxation. There was also less irritation of the mucous membranes. The early disappearance—presumably before true anæsthesia—of the reflexes, especially the ocular, is, he thinks, a drawback. The patients, after inhaling No. 3 solution, became cyanosed, the pulse slowed and grew weak, the pupils were dilated, while the respirations were shallow and rapid. Eventually the cyanosis became general, the breathing infrequent and feeble, and, with little warning, stopped altogether. This occurred in six cases which he witnessed, while in others profound circulatory depression, with heart failure, was seen. Retching and vomiting were, Rodman contends, as frequent as with other anæsthetics, nor was the return to consciousness more rapid or free from inconvenience. Upon the lungs and kidneys the effects were much the same as with ether. Bronchitis, followed by pneumonia, occurred in several cases, being in some instances fatal. Rhinitis and conjunctivitis were observed as sequelæ, and in three antecedently healthy persons albuminuria with casts in the urine followed the inhalation of the solution. Rodman further records a case in which heart failure of the most pronounced nature resulted from inhalation of No. 3 solution.† It would appear that after a somewhat extensive trial of Schleich's solutions their use has become very much restricted.

Wertheim's solution (1 part chloroform, 1 part petroleum ether, and 2 parts sulphuric ether) has been used in this country by Dr. Probyn-Williams.‡ It was administered from a mask —a modified form of Skinner's frame—and the experience gained from a limited number of cases is said to be favourable. Dr. Silk's § experience of Wertheim's solution has led him to

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* *Med. Rec.* (New York), Oct. 1, 1898.

† See an article in *Year Book of Treatment*, 1899, p. 177.

‡ *Trans. Soc. Anæsth.*, vol. iv. p. 98 : " A note on a modified form of Schleich anæsthetic mixture by R. J. Probyn-Williams, M.D., Harold Barnard, M.S., and Russell Howard, M.B."

§ *Trans. Soc. Anæsth.*, vol. v. p. 138.

believe that the petroleum ether which it contains is inoperative, so that the solution is practically one of sulphuric ether and chloroform. As such he considers it has some merits.

Chloroform and ether in various combinations and sequences. —A great variety of combinations and successions of these, besides those mentioned above, have been proposed from time to time, but need no special mention. (See chapters on Ether and Chloroform.) One point, however, must again be dwelt upon, and that is that either in the case of chloroform given before ether, or *vice versa*, great care and watchfulness must be employed, since in the one case the reaction from circulatory depression to circulatory stimulation, and in the other from circulatory stimulation to vaso-motor depression, may produce bad effects and even lead to accidents. Professor Julliard regards the plan as one " combining the dangers of chloroform with the inconveniences of ether."

Nitrous oxide and ether (see p. 173).

Continuous gas supplemented by ether.—Dr. Blomfield * points out that for many cases it is desirable to rely mainly upon nitrous oxide, and to supplement it when necessary by the associated use of ether. It is unnecessary to employ cumbersome apparatus. The plan he adopts is to use an ordinary Clover's inhaler, to which is attached a two-gallon gas-bag fitted with Hewitt's stopcock, connected with the gas cylinders. Induction having been conducted as usual and the expiry valve closed, the indicator is turned to full until anæsthesia is present, when it is rapidly returned to " O," so that the patient is rebreathing a mixture of gas and ether with expired air. The expiry valve is then opened and the gas-bag again filled to two-thirds of its capacity. This is rebreathed and the procedure repeated every five minutes. If any cyanosis appears air is admitted by opening the air-valve. If the narcosis becomes too light the indicator is moved, ether being admitted into the circuit. This simple method is less effectual for abdominal work, especially for operations in the upper abdomen. The addition of oxygen assists in securing relaxation.

The ethyl chloride and ether sequence is described on p. 321. It is an alternative to the nitrous oxide-ether method.

Ethyl bromide and chloroform.—The employment of these

* A Note on the "New Gas and Ether," by T. Blomfield, O.B.E., M.D. (*The Lancet*, Jan. 31, 1920, p. 253).

drugs *in succession*, similarly to nitrous oxide before ether, is, according to Terrier and Péraire, extremely useful. Otis (Boston) has suggested ethyl bromide 1 part, chloroform 3 parts, and alcohol 4 parts, and has employed it extensively in general and obstetric surgery. However, any sequence or mixture in which ethyl bromide finds a place is certainly dangerous.

Ethyl bromide followed by ether.—This method is advocated by Kocher of Berne (see above).

Chloroform vapour with oxygen.—This obvious combination was employed very early in the history of the anæsthetic. It has more recently been revived by Neudörfer and others. I have made many experiments with this combination, and although I cannot find any true physiological antagonism between chloroform and oxygen, such as is claimed by some, there is no doubt in my mind that for persons with a tendency to become cyanosed or congested, the employment of oxygen with chloroform is most valuable. I have used the oxygen *pari passu* with the chloroform without attempting a definite percentage dilution. Neudörfer employed 10 per cent. by the use of a special apparatus. A special apparatus is not, however, necessary. The method used can and should be extremely simple; for example, connecting the oxygen supply bottle with a nasal or mouth tube, so that one may give as much or as little of the gas as the patient requires. Kreutzmann makes use of Junker's apparatus, pumping oxygen instead of air through the supply tube. There is, however, a danger in this proceeding. The supply of oxygen to the patient masks the advent of cyanosis. When the Vernon Harcourt chloroform inhaler is in use, oxygen can be advantageously given by connecting the supply to a special tap fitted to the stem of the inhaler. The oxygen should be warmed by passing it through a tube immersed in hot water, whenever this is possible.

The value of oxygen given with chloroform consists in obviating any intercurrent asphyxia, as this causes rigidity, cyanosis, and impaired breathing. Oxygen does not antagonise the action of chloroform on the heart or nerve centres, although it protects the patient from the double danger which arises when chloroform is inhaled while the blood is in a condition of undue venosity. The chloroform, although still able to act prejudicially upon the tissues, is less dangerous when they are well oxygenated. It must not be forgotten, however, that overdosage is as liable to occur with as without oxygen, and, further, may arise without

the anæsthetist being warned of the danger by the appearance of cyanosis.

Chloroform and chloral.—The preliminary giving of chloral was first employed at the Hôtel Dieu by Dubois.*

Perrin used as large a dose of chloral as gr. 45 for adults, giving it one hour before the chloroform.

Dastre gives 2 to 5 grammes of chloral an hour before administering the chloroform by inhalation.† He explains the action of the agents thus : the chloral, acting as an hypnotic, composes the patient to sleep, and the tranquillity and lethargy of the patient enable the administrator to maintain true anæsthesia by the use of a small quantity of chloroform. The plan has been tried by Dolbeau, Guyon, and others, and they find the patients remain cold, faint, and collapsed for hours after the inhalation, and are peculiarly liable to hæmorrhage, owing to the relaxation of the vessels. There is no doubt in my mind that the method is fraught with danger, owing to the action chloral exerts upon the heart. Trélat adds **morphine** to the combination, and thereby, I think, increases its danger. These methods possess no advantages over that in which morphine, atropine and scopolamine are employed.

Cocaine and chloroform (Obalinski).—The plan recommended is to allow the patient to inhale chloroform in the ordinary way until he is slightly under its influence, and then to inject cocaine hypodermically. The dose is given as gr. $\frac{1}{3}$ to gr. $\frac{1}{2}$.

Rosenberg paints the nasal mucous membrane with cocaine before giving chloroform, as he contends this obviates reflex cardiac inhibition due to irritation of the fifth pair of nerves by the chloroform vapour.‡ However, cocaine does not antagonise chloroform, and the association of these drugs has been proved to be extremely dangerous, and so should not be employed.

Chloretone (Trichlor-Tertiary-Butyl-Alcohol) has been recommended for use before general anæsthetics in order to produce drowsiness and to lessen or prevent after-sickness. Fifteen grains are given by the mouth three hours before the inhalation. Chloretone evaporates slowly at room temperature, and so cannot

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* " Anesthésie Physiologique," par Dr. R. Dubois, 1894, p. 135.
† " Les Anesthésiques," p. 249.
‡ *Berliner Klin. Wochensch.*, Jan. 7 and 14. 1895.

be well sterilised by heat and does not maintain its strength if kept for any length of time.

The Anoci-Association Method.

Dr. G. W. Crile,* after some years of experimental research, supported by clinical observations, enunciated the Kinetic Theory of Shock. Shock, he contends, is in the main the result of exhaustion due to over-stimulation, itself brought about by trauma and the effects of drugs, *e.g.* strychnine, anæsthetics, and so on. The essential lesions of shock according to this view are in the cells of the brain, the suprarenals, and the liver ; and are caused by the conversion of potential energy into kinetic energy at the expense of certain chemical compounds stored in the cells of these structures. Motor activity is excited by the adequate stimulation of contact ceptors—that is, in the skin—and distance ceptors—that is, those of the special senses. Shock then becomes revealed as the result of the excessive conversion of potential into kinetic energy in response to adequate stimuli. The peripheral centri-seeking stimuli may be beneficial, and such are termed *bene-associations* ; or harmful, and such are called *noci*-associations. The problem, it is contended, is to establish a state of *anoci*-association as treatment of such conditions of shock as are revealed in all surgical operations. The aim of the anoci-association method then is to cut off the central nervous system from peripheral stimulations, and to avoid the introduction into the blood-stream of drugs or materials productive of noxious effects. Since the deleterious effects of trauma are brought about through conveyance along afferent nerve channels, blocking the nerves between the traumatised areas and the brain and impressionable organs should *pro tanto* protect these organs. Further, emotions, fear, anger, and so on, are capable of producing and actually do produce harmful effects on the brain even without surgical trauma, since they cause *psychic shock*. A patient operated upon under local or regional analgesia, or when the spinal cord is blocked by spinal anæsthesia, is subject to this psychic shock. Admitting these statements, anoci-associations can only be brought about when two conditions are

* *Anoci-Association,* by Dr. G. W. Crile and Dr. W. E. Lowes, 1914, *passim. Surgical Shock, Surgery of the Respiratory System, Problems relating to Surgical Operations,* and other monographs.

established—complete blocking of afferent nerve tracts and the production of insensibility. The first of these desiderata is secured by the employment of local analgesics, and the second by the giving of a general anæsthetic.

Histological examination of brain cells and observation of the adrenal output reveal that, after the administration of ether, urethane, nitrous oxide, and morphine, the brain cells are unaffected, and the output of adrenalin is not increased except in the case of ether during the stage of excitement. The normal adrenal output is diminished after morphine has been injected.

Comparing the effects upon the patient, Dr. Crile contends that deleterious effects are least promoted in the case of complete anoci-association, and most in that following ether administration. He found that the brain cells were damaged three times more with ether than with nitrous oxide and oxygen. He therefore relies upon nitrous oxide and oxygen to produce unconsciousness. It is beyond the scope of these pages to criticise Crile's conclusions or to enter at any length into the pathogenesis of shock. There can, however, be no doubt that, whatever views we may hold with regard to Dr. Crile's protocols, we must accept as a proven fact that an intelligent carrying-out of the technique of his anoci-association method offers a valuable plan whereby the patient can be protected from the effects of surgical trauma.

Technique of the Anoci-Association Method.

Dr. Crile insists that beyond the anæsthetic outfit there are certain purely surgical procedures essential to anoci-association. These are : that the cutting of structures must be done with very sharp instruments ; that no rough handling or dragging shall be practised, in order to avoid what he happily terms " insult to tissue " ; that the patient shall, both before and after the operation, be cheered by kindly consideration and shall be environed by an atmosphere of hopefulness.

Although details appropriate for special operations may vary, the procedure of the method is conducted on the following lines :

To mitigate pre-operation dread, a hypodermic injection of morphine gr. $\frac{1}{6}$ and scopolamine gr. $\frac{1}{150}$ is given one hour before the operation. Muscular or alcoholic persons may require morphine gr. $\frac{1}{4}$, although this dose is seldom needed. Extremes

of age and an enfeebled condition contra-indicate the use of narcotics. Deep morphinisation will, it is contended, almost completely abrogate shock. As morphine controls metabolic processes, its use is called in for cases of septic invasion. The nitrous oxide and oxygen mixture is then given. A slow administration is insisted upon and the necessity for pure gases emphasised. All tissues within a wide area of the region upon which the operative procedures will trench are carefully injected with 1 in 400 novocain. The initial injection is made endodermically, the deeper structures are injected layer by layer, and no tissues are divided until they have been infiltrated. The novocain solution is prepared from normal saline solution made with distilled water which has been boiled for twenty minutes. Novocain crystals are added, and the solution is boiled for ten minutes on two successive days. To prevent post-operation pain being experienced after the novocain effect has passed off, which occurs in about an hour, additional injections are made, a solution of quinine and urea-hydrochloride of the strength of $\frac{1}{6}$ to $\frac{1}{2}$ per cent. being employed. This infiltration should be *massive* and at some *distance* from the wound. The solution is prepared with the same precautions adopted as in the case of the novocain solution. Œdema of the area infiltrated occurs, and may persist for some weeks. It is claimed that no painful impressions will pass the infiltrated area for some days, and so the patient is unconscious of any discomfort in his wound. Local injection is contra-indicated when the area is septic. Unconsciousness is maintained until the patient has been returned to his bed.

In cases of exophthalmic goitre, the patient is anæsthetised with the nitrous oxide and oxygen mixture while in his bed, and is led to believe that this procedure is part of his treatment and will not be followed by an operation upon that day. This manœuvre is repeated several times on successive days until the patient is familiarised with the anæsthetic. Eventually on a subsequent occasion; after anæsthetisation the operation is performed.

CHAPTER VIII.

ANÆSTHETICS IN SPECIAL SURGERY, AND SPECIAL METHODS.

THE choice of the anæsthetic has been already˙ discussed˙; it now remains to consider such special methods and precautions as may be required to obtain satisfactory anæsthesia during the performance of regional operations, when they present unusual difficulty and need other than routine methods.

MILITARY SURGERY.

It has been pointed out * that military surgery resembles civilian practice except for the fact that soldiers in war cannot be properly prepared ; the rushes occurring at field-stations, call for rapid induction and recovery, and the orderly anæsthetic outfit present in civilian hospitals is impossible in the field. This is certainly true, but to appreciate the requirements of military surgery, the anæsthetist must make himself master of a number of techniques suitable for soldiers who fall into different categories, the diagnosis of which is at times difficult. Captain Geoffrey Marshall, R.A.M.C. (S.R.), of Guy's Hospital,† has carefully defined the conditions obtaining in casualty˙ clearing-stations, and detailed the methods which appear best suited to obtain satisfactory results.

The intrusion of the complex condition called Shock, whether due to trauma, insult to tissue, to exposure, to bursting of shells with general concussion, or to what is loosely called psychic perturbation, makes for increased complexity so far as the anæsthesia is concerned. It is, however, proposed to consider shock and its treatment, both antecedent to and following operation, during the unconsciousness of narcosis in a subse-

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* Flagg : " The Art of Anæsthesia," 2nd edition, 1919, p. v.

† *Proc. Roy. Soc. Med.*, 1917, vol. x., Proc. Section of Anæsthetics, pp. 17–36.

quent chapter which deals with the accidents arising during anæsthesia.

The problems of anæsthesia in war surgery to be faced are : the selection of the anæsthetic and choice of the method by which it is to be conveyed, and the ways in which the decision upon these points may be obtained.

Captain Marshall found nitrous oxide and oxygen, or *warmed* ether vapour given by Shipway's method, were best in the case of the lightly wounded. These men were usually unprepared for the anæsthetic, and often suffering from lung complications, *e.g.* bronchitis. Induction was commonly effected by mixed vapours, *e.g.* the A.C. or C.E. Local analgesia was contra-indicated, as the wounds were usually multiple, and were soiled and lacerated. Atropine was used whenever expectoration was present. In graver cases, shock dominates the problem. In these spinal anæsthesia is useful for operations on the lower extremities, especially if the wounds had been inflicted not less than forty hours before operation. In the case of the more recently wounded and in that of men suffering from profound shock, this method does not give satisfactory results, as symptoms of cerebral anæmia and heavy fall of blood-pressure follow the intrathecal injection, and at times prove fatal. This finding is also true when a severe hæmorrhage has occurred. Marshall regards the percentage of hæmoglobin as the best guide as to whether intrathecal injection should be made ; if it is low, precedent hæmorrhage has probably occurred and the method is inadvisable. A percentage of hæmoglobin of over 100 is satisfactory. It was found that the best way of preventing and combating collapse in these cases was attention to posture. The head should be lowered after fifteen minutes and kept low for an hour. On the other hand, we must remember that, although experience has shown that *fixation* of drugs introduced intrathecally is usually accomplished in fifteen minutes, this is not universally true. I have seen collapse occurring later, and presumably due to ascension of the stovaine injected. Strychnine (subcutaneous), pituitrin (intramuscular), are useless, and intravenous saline injection exerts only a temporary effect in raising blood-pressure.

In cases of severe wounds of the extremities, associated with shock, and requiring early operation, the following technique was found best. Morphine was withheld or given in small

doses (gr. $\frac{1}{4}$ or less), nitrous oxide and oxygen being the selected anæsthetic. If the interval between the infliction of the wounds and the time of operation is greater, and the primary shock has passed off, although the patient seems desperately bad and there is sepsis, often with severe vomiting, intravenous infusion of ether is indicated; but other methods of etherisation may be adopted, while nitrous oxide and oxygen or intrathecal injection of stovaine are permissible alternatives. Chloroform is contra-indicated. Captain A. S. Daly, R.A.M.C.,* agrees with Marshall's conclusions. He recommends that, when time allows, the patient should lie for an hour on one side, and then for an hour upon the other, to clear the lungs of fluid before the operation is commenced. He also emphasises the importance of employing a *light* narcosis in all the cases.

For operations for head injuries, local analgesia is said to answer well for the scalp tissues, but when bone has to be divided, warmed ether vapour by inhalation is called for, and the addition of oxygen undoubtedly helps.

Abdominal operations can be dealt with under warm ether vapour, preferably in association with oxygen. The intra-tracheal method is not mentioned by Marshall, probably be-cause the requisite apparatus would not be available in casualty clearing-stations, but when obtainable, it should prove of value. Except in cases in which a perforating wound of the chest com-plicates the abdominal condition, chloroform is said to cause too great a fall of blood-pressure. Possibly, too high percentages were employed; but all those who have gained experience in war surgery are emphatic about the danger of chloroform when shock is present, and their warning cannot be disregarded. When a perforating wound of the chest complicates the abdominal condition, a preliminary hypodermic injection of morphine, scopolamine, and atropine is advised, and a low percentage warmed vapour of chloroform given with oxygen. In spite of negative evidence, I believe that all ether cases should be guarded by a preliminary injection of atropine, as it not only protects against water-logging of the lungs, but also assists the heart. Saline intratissual injections may do good, and so should be employed, provided excessive quantities of fluid are not intro-duced. In all severely shocked patients, and especially when the abdomen is the site of operation, rapid and gentle manipulation

* " Manual of War Surgery " : Barling and Morrison, 1919, p. 429.

without dragging viscera outside the abdomen is essential. Turning a patient upon his side is dangerous, especially after prolonged anæsthetisation.

Captain H. C. Bazett, M.C., R.A.M.C.,* writing upon the avoidance of shock, has found an injection of morphine, atropine, and scopolamine given before the anæsthetic valuable, but Captain Marshall † reports adversely to such medicament for cases of marked shock present before operation. Captain Bazett agrees in the main with the statements given above. He insists upon a light narcosis, the avoidance of chloroform, the use of nitrous oxide and oxygen, or warmed ether, and spinal anæsthesia in suitable cases.

In Civil Surgery.

Operations on the brain and spinal cord.—The method which answers best when the brain is being operated upon is to employ chloroform in association with oxygen from the Vernon Harcourt apparatus shown in fig. 54, pp. 250 *et seq.* When a dosimetric apparatus is not used, extreme care is necessary to maintain a light although sufficient narcosis. It is often extremely difficult to obtain anæsthetic sleep in patients who have taken large doses of narcotic drugs commonly employed in these cases, so that the induction period is frequently prolonged. Any attempt to hasten anæsthesia by using strong percentages is extremely dangerous. On the other hand, many persons who have to be operated upon for brain or meningeal disease are, at the time of taking the anæsthetic, very prostrate and semi-comatose, or suffer from the results of intracranial pressure. These condi· tions render interference with the circulation and respiration dangerous. The patient, when once anæsthetised, will often remain unconscious with little, or without any, more of the anæsthetic. As a rule, when the intracranial pressure is relieved the respiration greatly improves, but until the cranium has been opened and the dura mater incised, breathing may be very unsatisfactory, and may even cause alarm if, owing to the steps of the operation, increased pressure occurs. When the breathing

* " Manual of War Surgery ": Barling and Morrison, 1919, p. 402.
† In a letter Captain Marshall tells me that the resumption of consciousness, even when the mixture of nitrous oxide and oxygen has been used, is much delayed when scopolamine has been injected.

is at all hampered the chloroform should be withheld altogether for a time, until it improves, when more chloroform can be given, care being taken that the strength of the vapour is as slight as is consistent with maintenance of complete anæsthesia.   As a rule, when induction is complete, 0·5 per cent. to 1 per cent. is sufficient.   In operations upon the **cerebellum,** the dangers of respiratory failure and shock are even more imminent, especially if there is pressure on the medulla.   It may happen that, as soon
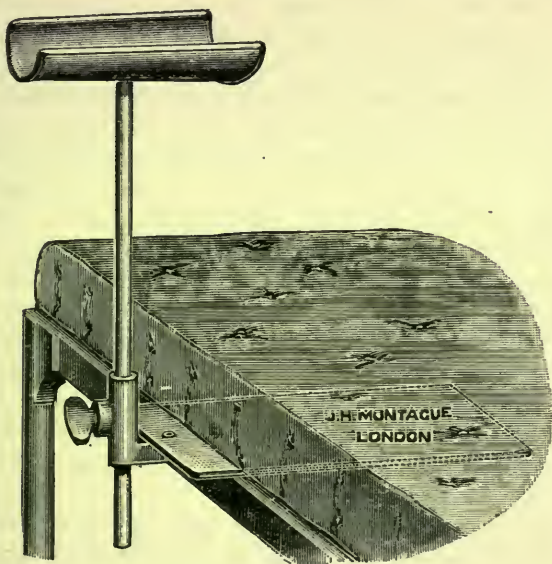
FIG. 79.—Carter Braine's arm-rest.

as the trephine is applied, the breathing ceases.   If the patient has been deeply anæsthetised, death is very likely to follow ; but if only 1 per cent. of vapour is being inhaled, the chances are in favour of the life being saved, since, as soon as the pressure is relieved, the breathing starts afresh, and the blood-pressure rapidly regains its normal height.   I have known cases of cerebral and cerebellar abscess in which this respiratory failure occurred ; as, however, only small quantities of chloroform had been inhaled the patients recovered, and the operations were satis- factorily completed.   Some authorities dissent from the view that ether is contra-indicated in the surgery of the brain and spinal cord.   Its use, however, is undoubtedly associated with

vascular excitement, and involves a loss of blood which the patient can ill afford. Even if his condition appears favourable at the time of operation, it becomes the reverse in an hour or so later, when collapse is frequently developed. In civil practice local analgesia, even if followed by the use of a general anæsthetic, is not altogether favourable. Possibly an exception to this statement may be made in cases of cerebellar abscess, when the pressure is extreme and the patient's respiration is very seriously affected. Even then the delay incident to the plan is not desirable even if it is considered safe. In treating the collapse—often very severe—I have found inhalation of warmed oxygen, raising the temperature of the body by the use of hot-water bottles, and towels wrung out of hot water, and hypodermic injections of digitaline, to be the most valuable means to adopt. The anæsthetic vapour also may be warmed with advantage and a heated operating table employed. The circulatory depression is often extremely severe.

The posture of the patient during intracranial surgery is important. The head must be kept high, and the uppermost arm kept off the chest by the use of an arm-rest. That of Mr. Carter Braine is an excellent device. Experience with hedonal infusion has not realised the first hopes entertained of its use in these cases. The use of a special head-rest such as Cushing's greatly facilitates these operations. It is described in Chapter X. in the section dealing with Posture.

For the complete operation for removal of the Gasserian ganglion ether causes too much oozing, and so should not be employed.

Operations upon the spinal cord present similar dangers, from the point of view of the anæsthetist, to those which occur when the brain is the seat of operation. In them, also, it often happens that, owing to the lesion in the cord, the respiration is embarrassed *ab initio* through paralysis of the muscles concerned in the respiratory movements. The posture necessary for the performance of the operation is a further source of difficulty and danger. Chloroform should be employed in these cases, and in very dilute vapour, and oxygen freely given to avoid any asphyxial complication. When anæsthesia is established, no more chloroform need be given unless the patient begins to regain consciousness or shows signs of vomiting. It is often surprising how little—1 per cent. or less of chloroform—is

required to maintain anæsthesia in these cases. The lateral posture is best with the uppermost arm kept off the chest by means of an arm-rest. The head should be flexed on the thorax. The arm-rest checks the tendency for the patient to roll over on his chest and so interfere with his breathing. It is better to avoid giving scopolamorphine in operations upon the central nervous system.

ANÆSTHETICS IN OPHTHALMIC PRACTICE.

Most of the operations performed are done with the aid of cocaine, novocain, benzamine (β-eucaine), or other local analgesics, and the reader is referred to the chapter dealing with these substances. When general anæsthesia is desired, the choice lies between chloroform, ethyl chloride, some mixture—$e.g.$ the A.C.—or the gas and ether sequence. As extreme stillness is a necessity in operations such as iridectomy, narcosis must be of the third degree, and great care must be taken that this is maintained lest coughing or straining occur, as these might prove most disastrous. Even with great care it is not always easy to prevent the patient passing into the fourth degree of narcosis. This contingency must be looked for carefully and prompt measures taken to avoid the great danger of overdosage. Deaths have been caused by neglect of this. It is of paramount importance that the operation should not be commenced until the patient is profoundly narcotised. When anæsthesia has been obtained, the mask, or inhaler, can be lifted from the face, and as a rule the operation can be finished without any further inhalation being required. In very feeble or asthenic subjects, I have employed the following routine. A preliminary hypodermic injection of atropine is given an hour·before the operation ; sometimes, but not always, morphine and scopolamine are added. Induction is then pursued with either (1) nitrous oxide and oxygen followed by ether vapour, preferably warmed, *and oxygen* ; or (2) by dropping A.C. solution on a Schimmelbusch mask, and following this with ether. In either case the ether is given from a closed inhaler as profound narcosis is requisite. A small face-piece usually is out of the way of the surgeon, but in ·some cases I have employed a special shape, a truncated

cone which attaches to the inhaler at the chin end. It is made
of celluloid to enable the anæsthetist to see the patient's face.
If chloroform is used a small light wired mask can be adopted,
which just covers the bulbous portion of the nose and the mouth.
In this way maintenance is easily effected. For brief operations
ethyl chloride answers very well, but in cases in which after-
vomiting is likely to prove dangerous, ethyl chloride should be
avoided and nitrous oxide and oxygen should be substituted.
Personally, I prefer the latter sequence to ethyl chloride, although
I admit it is more difficult to ensure equal and placid anæsthesia,
For excision of the eyeball the gas-ether sequence is excellent,
especially if oxygen is freely admitted throughout the operation.

ANÆSTHETICS FOR OPERATIONS ABOUT THE FACE, NECK, MOUTH, JAWS, AND RESPIRATORY TRACT.

For major operations when the operation area must be left
free, choice of anæsthetic and method lies between the intra-
tracheal ether (often the best), the colonic oil-ether, and the intra-
venous ether methods; the sequence of nitrous oxide followed
by ether from a closed inhaler; and, finally, chloroform presented
by intratracheal insufflation, or chloroform vapour driven
through a nasal or buccal tube (intrapharyngeal) method.
An alternative plan which possesses many advantages is to
induce by ether or a gas and ether sequence, perform tracheotomy,
and then, by employing a Junker's apparatus, propel chloroform
through a vapour tube which delivers over the tracheotomy
tube. The tube can be completely sterilised, and it and the
hand of the anæsthetist can be enfolded in a sterilised towel
and so kept out of the surgeon's way. The anæsthetist sits
by the side of the patient. This procedure is of great value
in extensive operations on the mandible and in those upon
glands in the neck. In all these cases atropine, or atropine,
morphine, and scopolamine, should be given hypodermically
one hour before the anæsthetic. Hedonal must *not* be used in
these cases. Chloroform can be used safely when the Vernon
Harcourt inhaler worked by a *plenum* system is adopted
(see p. 257). Crile's nasal tubes render intrapharyngeal
anæsthesia by chloroform or ether a simple proceeding. The
intratracheal method of giving chloroform referred to above is
carried out as described below.

Intratracheal Method of Giving Chloroform.

Mr. C. H. Mott * has employed this method in 357 cases, and speaks highly of its value. He adopts the Kelly type of intra-tracheal apparatus, introducing a second chamber. A flow meter is added which gives readings up to 30 litres of air per minute. When 16 ounces of chloroform are placed in the chamber, a dial on the chloroform tap indicates the percentage of chloroform vapour delivered, when the motor drives 10, 20, 30, or 40 litres of air per minute through the chloroform. Professor A. D. Waller has graded this dial. Mr. Mott gives an injection of morphine and atropine before the general anæsthetic. The untoward symptoms were few, it is stated, and were remedied by altering the percentage of chloroform given or by cutting it off. The addition of ether or oxygen is easily effected. Of the eight cases of death, none were due, it is said, to the anæsthetic. The complications were also few and slight. The method was used for operations upon the air-passages and other surgical procedures.

When **ether** is to be relied upon solely for operations on the **mouth** or **nose,** and is given from a closed inhaler, it is essential to obtain a very profound narcosis by it before the operation is commenced. This can only be done by allowing a prolonged period of full inhalation. Oxygen given with the ether facilitates this, and ensures a more lasting and profound narcosis. I have on more than one occasion given ether, the circumstances of the cases contra-indicating another anæsthetic, for removal of the upper jaw, and found the method extremely satisfactory.† It is sometimes necessary to prolong the anæsthesia by giving chloroform through a mouth tube connected with a Junker's apparatus.

During the removal of the upper jaw the patient must be kept deeply under the anæsthetic for the skin incisions. A choice of several methods exists. In the case of feeble people or those broken in health by alcoholic excess the induction of anæsthesia may be brought about by nitrous oxide and oxygen followed by ether, chloroform being given subsequently

* *Lancet,* 1919, vol. ii. p. 1197.

† Ether vapour can be blown through a Junker's apparatus if it is kept warm enough to avoid the tubes getting " snowed " through rapid ether evaporation.

from a mask. As, however, this plan may cause congestion and increase the after-bleeding, I often commence with chloroform, using a Vernon Harcourt's inhaler, and, when the third degree is reached, give a few breaths from a mask, continuing the supply of chloroform by means of a mouth tube and Junker's inhaler. Some persons are difficult to keep quiet with the mouth tube. To meet this, the mask may be applied, as opportunity arises, to supplement the vapour passing through the tube. When the skin flaps and soft parts are freely divided and dissected up, the patient must be allowed to enter the second degree of narcosis, so as to be able to cough and prevent blood entering the larynx, although he should be sufficiently anæsthetised, so as not to struggle. The management of these cases needs constant care and some judgment. The dangers the chloroformist has to guard against are—entrance of blood, teeth, portions of growth, spicules of bone, into the larynx ; and interference with the operation by the patient becoming partially conscious. When chloroform is given by way of a tracheal tube, it must be remembered that the vapour will enter the lungs without further dilution. This is because the dead space of the buccal and pharyngeal cavities is cut out, and the dissipation of the anæsthetic which occurs when the patient inhales by the usual oro-nasal channels does not arise when the vapour is propelled directly into the trachea. This remark applies with equal cogency to intratracheal insufflation methods. If struggling occurs when there is much hæmorrhage, the danger of the operation is greatly increased. The chloroformist should see that the spurting of blood from vessels is directed out of the mouth ; that the tongue is not allowed to fall back ; and that the air enters and leaves the lungs freely. To avoid the falling back of the tongue if its attachments are divided, a ligature should be placed in the organ before the operation is commenced and the tongue kept forward by securing the ends in a catch forceps. The needle introducing the ligature should be introduced across the long diameter of the tongue, as this prevents it tearing out when it is drawn upon. If the patient's respiration is embarrassed from entrance of blood into the air-passages, the tongue must be drawn well out of the mouth, all blood mopped away, and, failing relief from this, laryngotomy performed and the air-passages cleared of clot ; subsequently the tube must be kept free from clots, etc., by aspiration, or

by sucking them out from the tube.   Inversion may be needed.

Removal of the lower jaw may often be done almost completely while the patient is under ether, the ether being given in the manner already described, and chloroform administered only just at the last when, in the course of the operation, the mouth is opened.   This is an admirable method.   Many surgeons prefer the use of chloroform throughout the whole operation. The method to be pursued is described above.

In excision of the tongue the patient, having been anæsthetised by nitrous oxide or ethyl chloride followed by ether, and finally by chloroform, one of the methods already described being adopted, chloroform is subsequently administered through a nasal or mouth tube.   The same precautions with regard to hæmorrhage should be taken as in anæsthetising for removal of the jaws.   When much bleeding occurs the patient must be guarded from deep narcosis, so that the cough reflex may prevent blood entering the air-passages.   In Kocher's operation ether can be used until the floor of the mouth is opened, and the tongue drawn out of the wound ; at this point chloroform is exhibited through a nasal or mouth tube.   Many prefer the use of chloroform throughout the operation.

When small growths are removed from the tongue, nitrous oxide or ethyl chloride answers perfectly well.   The nitrous oxide anæsthesia may be maintained by using the " injector," or Coleman's nasal apparatus, while the surgeon is operating, although the venous congestion which is incidental to these methods is a detriment.   Preliminary injections of scopola-morphine and atropine are advisable in all these cases.

The problem presented by the occurrence of hæmorrhage during anæsthesia is considered in Chapter X.

In Minor Operations.—The extraction of teeth is dealt with elsewhere. (See Nitrous Oxide, p. 65 ; Local Analgesia, Chapter XI.) When loose sequestra have to be removed from the jaw, an epulis excised, small growths taken from the tongue, an abscess of the antrum of Highmore or frontal sinus opened, a prolonged anæsthesia is not required, and intrapharyngeal methods of giving nitrous oxide, ethyl chloride, ether, or chloroform are satisfactory.   If nitrous oxide given first by the mouth and then nasally is not considered satisfactory, atropine having been given, the gas and ether sequence may be used **for**

induction. A Junker's apparatus charged with chloroform should be at hand with a mouth tube or nasal catheter attached, to be used if the operation becomes more prolonged than was anticipated.

A simple examination under an anæsthetic may prove very difficult if there are sinuses leading into the pharyngeal cavity, and they are not covered by the mask in use. Such cases should have a heavy dose of morphine guarded by atropine, and the mask surrounded by a wet towel to prevent air entry and blowing out of the chloroform or ether, whichever is in use. In all minor cases the anæsthetist should be careful to obtain full anæsthesia before the operation commences, as when maintenance is to be obtained by the intrapharyngeal route, the depth of narcosis is tolerably sure to lighten, and the patient may easily pass back into a state of excitement .

Staphylorrhaphy.—Chloroform or a chloroform mixture is usually employed in this country, certainly in the case of young children, and an open method adopted. In adults the gas ether sequence may precede the chloroform, but it is liable to cause more bleeding, which is embarrassing to the surgeon, and so had better be avoided if the operation is at all likely to cause difficulty. The Whitehead's gag is then fixed, chloroform being inhaled through a mouth tube. The tongue depressor should be so arranged as not to interfere with respiration. The chin is best tilted up a little, because, if it is allowed to drop, breathing is always hampered. Anæsthesia can be perfectly well maintained in this way until the operation is complete. Mr. Warrington Haward tells me he has used ether successfully for these cases, but I have no personal experience of its use in this connexion, except when given by the rectal route, a method which answers very well. The hæmorrhage being, as a rule, slight and easily controlled, there is no particular fear of blood entering the trachea, and further, as quietness is very desirable in the patient, full surgical anæsthesia should be maintained. Some surgeons employ the semi-inverted position for these operations, and this posture certainly lessens the danger of blood entering the larynx. When, as in the case of young children, a hare-lip operation is performed immediately after the staphylorrhaphy, it is wise to lighten the narcosis before the second procedure is entered upon, as closing the cleft in the lip commonly makes it difficult for the infant to breathe,

and respiratory difficulty renders deep chloroform narcosis a definite peril in these cases.

Operations on the respiratory tract.—**Laryngotomy or tracheotomy** is best performed when the patient is under chloroform or some mixture. It can be carried out quite satisfactorily with ether, provided respiratory embarrassment is absent. When dyspnœa exists, chloroform should be employed, its use being so restricted that the patient is only lightly narcotised; but full anæsthesia must have been attained. Any dulling of the respiratory centre is to be avoided. In cases of diphtheria the heart is always profoundly affected by the disease, and is peculiarly liable to suffer from even slight excess in the strength of the chloroform vapour inhaled. It is very important in such cases to adopt a method which allows of definite dosage being practised, so that the amount given can be accurately known and the supply cut off at any moment. If œdema of the tissues about the trachea exists, whether due to inflammation (angina Ludovici), renal disease, or angio-neurotic œdema, ether and nitrous oxide are absolutely contra-indicated. If the œdema is not due to septic causes, local analgesia can be readily produced by novocain and adrenalin, and, failing this, the anæsthetist must rely upon the chloroform and alcohol mixture.

Operations upon the thymus.—These are seldom attempted in this country, nor is their necessity likely to arise save in most exceptional cases. They are usually performed under chloroform unless local analgesia is relied upon. As the patients are extremely young, local methods usually fail to ensure the quietude essential to the difficult and hazardous character of the case, and so had better be avoided.

Operations on the thyroid gland.—In cases of simple adenomata no special difficulties arise unless the growths are of a large size or encircle the trachea and so cause obstruction to the air-way.

The methods commonly employed are (1) Local analgesia with preliminary injection of alkaloids; (2) General anæsthesia; (3) A combination of local analgesia and general anæsthesia (Crile's method).

1. Although the pain of the operation can be mitigated, it is usually rather severe when the growth is being displaced from its bed, and the dragging incidental to the procedure interferes with respiration and lowers blood-pressure.

Braun advises the use of novocain (0·5 per cent.) and adrena-

lin : 75 to 125 c.cm. are injected, but it is advisable to give
a preliminary hypodermic of scopolamorphine. The skin is
infiltrated (see below, Chapter XI.) fairly wide of the margin of
the growth ; subsequent subcutaneous and subfascial injections
are made until it is assumed that the nerves supplying the area
to be dealt with have been brought under control.

In cases of **exophthalmic goitre** the dangers to be faced are
of a very much more serious nature. Not only is there the shock
incident to the operation, but there is in these cases a very
real danger of sudden heart failure often arising from a dispro-
portionately slight cause. For these patients some authorities
contend that local analgesia, by not abrogating " psychic shock,"
does not free the patient from risk, and suggest the employment
of scopolamorphine before local analgesia or Crile's full technique.

2. **General anæsthesia.**—(a) Chloroform given by a regulating
inhaler subsequent to scopolamorphine and atropine is, I think,
less dangerous than is often stated. The atropine dries up the
bronchial and salivary secretions, which are apt to be excessive
in persons with goitre. The narcosis, after anæsthesia is estab-
lished, should be light with the conjunctival reflex just present,
and oxygen should be freely given. Slight reaction when the
thyroid is dislocated is desirable.

(b) Open ether after atropine is a fairly safe procedure, pro-
vided no venous congestion is allowed to arise.

(c) **Crile's method.**—Nitrous oxide and oxygen is given daily
(Teter's method), the patient being told this procedure is for
treatment, while the real date of the operation is kept a secret.
On the day that the thyroid is to be dealt with, a hypodermic
injection of scopolamorphine is given and nitrous oxide is ad-
ministered. The patient is then taken to the operation theatre,
and the operation area infiltrated with novocain. The operation
is then performed, and the nitrous-oxide-oxygen anæsthesia
is kept up until the patient has been taken back to his room
and replaced in his bed (see pp. 350–2).

In my own practice I have commonly used **chloroform** and
oxygen, and have found the method satisfactory. The use of
ether is open to two objections : it causes the tissues to weep
and so prolongs the operation, and tends to after-bleeding ; it
misleads the surgeon and the anæsthetist as to the true condition
of the patient. While under the stimulating effect of this
anæsthetic the patient is apt to appear spuriously free from

shock, and the anæsthetist may be apt to form too optimistic a view of his condition, while the surgeon may perform a more radical operation than he at first contemplated. As soon as the ether inhalation is stopped, however, the patient falls into grave shock, so that the chances of his ultimate recovery are materially prejudiced. I know of one case at least in which the patient succumbed in a few hours from this cause. If ether is decided upon as the anæsthetic to be used, the vapour should be warmed and given with oxygen by the intratracheal method; but atropine must have been given an hour before.

Excision of the larynx.—Thyrotomy requiring a preliminary tracheotomy may be performed under chloroform. After anæsthesia has been induced by ordinary methods, tracheotomy is performed and the upper end of the trachea is occluded, a Hahn's tube being used. However, an ordinary tube answers the purpose. In the case of the Hahn's tube, chloroform is given by sprinkling it on a flannel stretched across a funnel connected with the tube, or in the case of the ordinary tracheotomy tube, the chloroform is given by using a metal tube and the Junker apparatus, the tube being held over the opening in the trachea. An alternative is mentioned below.

Bronchoscopy.—Chloroform is, as a rule, the best anæsthetic for induction, but the passage of the instrument is rendered easier if the larynx and epiglottis have been sprayed with cocaine solution (5 per cent.). *Complete* anæsthesia is required, as laryngeal spasm, always liable to occur, is more pronounced during a light narcosis. It is also desirable because, if any difficulty arises during the introduction, the surgeon may require some minutes, during which the patient will not receive any anæsthetic, and so is liable to struggle unless well under chloroform. A Junker's inhaler with mouth tube should be at hand to maintain anæsthesia until the bronchoscope is safely passed. When this is done it is easy to maintain the due depth of narcosis.

These rules apply *ceteris paribus* to the passage of the endoscope into the pharynx and stomach.

RECTAL ETHERISATION IN ORAL SURGERY.

During operations for the removal of the tongue, the jaws, as well as for staphylorrhaphy, also for excision of the larynx,

the rectal etherisation method is far more convenient for the
operator than the plans named above in which chloroform is
used. This is also true of Gwathmey's oil-ether rectal method.
The operation can be carried on without a break. However,
as some alarming and even fatal results have occurred under
the care of skilled anæsthetists, it must be admitted that rectal
etherisation is not wholly devoid of danger. In most cases,
although not in all, the after-effects are slight and not lasting.
I regard the method as a valuable alternative one in suitable
cases. When much blood is likely to be effused into the buccal
cavity, careful watch will have to be taken that it is efficiently
sponged out, and does not enter the windpipe.* If the anæs-
thetist is engaged in watching the apparatus at the foot of the
operating table, another observer should be stationed at the
head to watch the respiration. In all these cases the inverted
posture of Trendelenburg may be usefully employed. I am
inclined to believe that in this branch of surgery the intra-
tracheal method is safer in skilled hands than is rectal etherisa-
tion or colonic injection of the oil-ether mixture.

Ether infusion for all the above operations answers well, but
in its use, again, the anæsthetist must take all the requisite pre-
cautions against blood entering the air-passages and other causes
of interference with respiration. I have never used this method
for cases of staphylorrhaphy in children, and should hesitate
to do so, as chloroform appears to me to be better adapted for
them.

REMOVAL OF POST-NASAL ADENOIDS, NASAL SPURS, AND INTRANASAL OPERATIONS.

The removal of growths in the post-nasal region may give
rise to troublesome bleeding. Chloroform, preferred by many
surgeons, possesses the disadvantage that the patient remains
longer under its influence, and so it is less easy during its use
to avoid blood entering the air-passages. Complete anæsthesia
is essential, although the narcosis should be light, in order that
the larynx may be protected by its reflexes against the entrance
of blood. Deep anæsthesia is most perilous, and many deaths
have occurred during these operations.

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* Especially is this important if the anæsthesia is profound and the
reflexes annulled.

Many authorities assert that the anæsthesia obtained by nitrous oxide given with oxygen or air is sufficient for removal of post-nasal vegetations. In some cases this may be so, if the anæsthetic is carefully managed. I have found the nitrous oxide may be supplemented by the use of ether with most satisfactory results. There is no objection to the patient being placed in a chair, *provided chloroform is not given*.

In some **nasal operations** a lengthened period of anæsthesia is required, and then chloroform must be used in succession to the gas and ether, and respired through a mouth tube. The following technique for intranasal operations is adopted by some surgeons. The patient is placed in the supine position, and a preliminary hypodermic of morphine and atropine, alone or with scopolamine, is given and the mucous membrane cocainised. Induction is carried out by gas and ether, the A.C., the C.E. mixture, or by chloroform; of these I prefer the first, and supplement its use with oxygen to prevent any congestion of the tissues. The nasal plugs are then removed, the mouth is opened by means of a Doyen's gag, and the posterior nares are plugged to prevent blood passing backwards and trickling into the larynx. The tongue is secured either by a clip gag (fig. 14, p. 75), or by a ligature passed transversely in the lingual substance, and fixed so that retraction is impossible; the latter is the better, as after-discomfort is less. The mouth is then nearly closed, but the gag kept *in situ*, and the shoulders are raised to a height convenient for the surgeon. The anæsthesia is deepened by dropping chloroform on an open mask. When a sufficiently deep narcosis is obtained, the palate being relaxed and no straining or cough being produced by the steps of the operation, maintenance of anæsthesia is then secured by introducing chloroform vapour from a Junker's apparatus through a mouth tube. The intratracheal method of administering gas and ether with oxygen has some advantages, but I have no experience of its use in this connexion. For delicate children who fear " gas," ethyl chloride answers very well for brief operations.

It has been stated by some anæsthetists that chloroform may be used even if the patient is in a sitting posture. Although the plan they adopt is to induce anæsthesia by ether or an ether-chloroform mixture and maintain it with chloroform vapour blown through a Junker's apparatus, I consider the method is

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not free from danger, especially if the patient is delicate or the respiratory obstruction is marked.

In another method adopted for post-nasal operations, the patient, if sitting up, is given gas and ether by Clover's method. When gas alone is used, it is well to put a dental prop, or Doyen's gag, in position before commencing the administration, otherwise much valuable time is lost in attempts to open the mouth. When the patient is well under ether, the induction being so managed that no lividity or congestion is present, the mask is removed, the gag inserted, and the operation commenced. If the patient becomes restless before its completion the mask can be reapplied, the head being tilted forward and flexed, so that the blood passes forwards and not into the air-passages. If the patient is reclining, chloroform can be given through a mouth tube as soon as the operation is commenced, the amount being carefully regulated by the requirements of the patient, and withheld entirely if any interference with breathing occurs.

As soon as the operation is completed the patient should be turned right over on to his left side and laid with the head in such a position that the blood must escape out by the nostrils and mouth. Some surgeons keep their patients on the left side throughout the operation.

Of course, when the cautery is to be used in the nasal passages, ether must be avoided. For cauterising the turbinate bodies nitrous oxide or ethyl chloride can be used.

Tonsillotomy can usually be performed under the nitrous oxide and ether, or the ethyl-chloride-ether sequence. The open ether method will prove less satisfactory, as the degree of anæsthesia is so slight that, unless the operation is very rapidly performed, the patient will struggle.

Tonsillectomy, as commonly performed, requires a longer period during which the anæsthetist is debarred from complete access to the mouth and nose. Many surgeons ask for a deep degree of narcosis so that the palate and faucial arches are flaccid and no reflex movements of the pharynx and larynx occur. To this end they often select chloroform for both induction and maintenance. The technique described above answers well for these somewhat anxious cases.

These methods are suggested for simple growths or hypertrophy : when a sarcoma or other malignant tonsillar growth

has to be removed, intratracheal ether insufflation or ether-infusion is probably the best method for adoption.

ANÆSTHETICS IN DENTAL SURGERY.

The operations for which an anæsthetic is usually needed are :—

Extraction of teeth ;

Lancing the gums, and tapping the antrum ; slitting the frænum.

Extirpation of the dental pulp ;

Filling when the dentine is abnormally sensitive.

In tooth extraction, nitrous oxide gas—alone, or with air or with oxygen—is the safest and most convenient anæsthetic.

The technique of the use of this anæsthetic is fully described on p. 76.

As a rule, it is inadvisable to administer gas twice to the same patient at one sitting, and if such a thing is done warning of probable after-headache should be given.

When prolonged anæsthesia is required, nitrous oxide may be given by the nasal method. I find it convenient to commence in the ordinary way with gas, or gas and oxygen, and when the mask is removed and the operation commenced, I apply the nasal inhaler and continue the gas as long as is necessary. When a Coleman's apparatus is in use this complication is avoided, as the mouthcap is simply dropped and the patient continues nasal inhalation. If the patient becomes dusky or jactitates, the inhaler is lifted for a breath and then is replaced. This plan is less useful in extraction of upper teeth, especially if the lip is short or pulled forward by a prognathous jaw. Ethyl chloride is valuable in suitable cases for prolonged dental operations, but possesses the disadvantage that it is liable to provoke nausea. With 5 c.c. or 8 c.c., according to the physique of the patient, an anæsthesia can be obtained lasting sufficiently long for clearing the jaws.* *Chloroform should never be given to a patient sitting upright in a dental chair.* If it is deemed wise to employ chloroform, the patient should be seen at his own

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* Dr. Kingsford points out the danger of a second administration of ethyl chloride to the same patient at one sitting. The first death after 17,000 successful cases of this anæsthetic occurred at a London throat hospital during a second administration.

home, and in bed, and the anæsthetic administered with the usual precautions. Indeed, I think it is always best, when an extensive dental operation has to be done under an anæsthetic, that it should be performed in the home of the patient and under ordinary surgical conditions. The gas-ether sequence following an injection of atropine is the best routine method for extensive dental operations. The ether should be given freely.

THORACIC SURGERY.

In the surgical treatment of empyema some difficulty frequently arises in the choice of the anæsthetics. For short operations, such as exploratory aspiration, nitrous oxide with oxygen answers very well, and this mixture offers many advantages. It is given in the usual manner, but as soon as anæsthesia is obtained, oxygen is freely admitted. Many patients complain that the mask increases their distress and dyspnœa. Ethyl chloride is free from this drawback if given carefully by the open method. If the dyspnœa is at all severe or the heart is displaced, it is better, I think, to rely upon chloroform and oxygen given, if possible, from a regulating inhaler, as the patient suffers far less discomfort and does not incur any greater risk. The real dangers of the anæsthetic in these cases arise (1) from the fact that, unless the anæsthetist is familiar with them, he is liable to push the anæsthetic too far and obtain a deep narcosis, and (2) from the incautious movement of the patient to assist the performance of the operation, as this will still further hamper the already embarrassed respiration.

Prolonged operations.—Chloroform in a good many instances has caused dangerous and even fatal results from syncope, while ether sets up severe cough and respiratory distress. Sir Rickman J. Godlee,* whose experience of these cases is very large, advocates chloroform provided it is given slowly, and a light degree of narcosis is maintained. I believe that chloroform is, upon the whole, the safest anæsthetic in thoracic surgery, especially in the form of the (1 in 10) alcohol-chloroform dilution. If pure chloroform is used it should be given from

* " Disease of the Lungs," by Sir Kingston Fowler and Sir Rickman Godlee, London, 1898, p. 114.

a **regulating inhaler,** and **oxygen** freely mixed with it. It must be remembered, however, that some patients will not submit to any mask being placed closely over the mouth, as it suggests, even if it does not cause, dyspnœa. For these an open method must be adopted with the preliminary use of atropine, but morphine should be avoided.

For resection of ribs the patient is slowly anæsthetised, and as soon as he passes into the third degree the tissues are divided down to the rib. He is then passed into the second degree, and this suffices for the rest of the operation. If there is a large amount of secretion, the lighter the narcosis the greater will be the patient's safety. Any change of posture must be carefully noted, and if the breathing is impeded, or coughing excited, the patient must be replaced in the posture of greatest ease. It is often a good plan in very severe cases—*i.e.* when grave fears exist owing to the condition of the heart and lungs —to push the anæsthetic to only the first degree, as far as possible maintaining a state of analgesia, and always stopping short of true anæsthesia. To combat these difficulties I have employed the method of rectal etherisation (*q.v.*) in thoracic surgery, and have been pleased with the results, especially in the case of children. It is essential, however, in using this method to avoid too deep a narcosis. In one case I met with a serious complication. The lungs became waterlogged owing to the cough reflex having been lost. This was in a young subject, but inversion drained the fluid out of the sound lung and the operation was then completed and the child did well. When an empyema communicates with a bronchus, great care must be taken that the patient does not become narcotised so deeply as to hinder free coughing up of the pus in his lungs. A great danger arises, when the patient is turned on his sound side, lest the pus should flow into the bronchi of the healthy lung. If this occurs when the patient is deeply under the anæsthetic, asphyxia must result. Any appearance of cyanosis should be accepted as a sign to lessen the depth of the narcosis.

Intratracheal insufflation, provided there is not much pulmonary secretion, and no communication exists between the abscess and a bronchus, is probably the best method in thoracic surgery, as it ensures a plus pressure in the lungs.

For some cases **conduction analgesia** answers well. The thoracic nerves are sought for at the points where they divide,

the anterior branches running in the groove on the under border
of the ribs, and novocain injected about them (see Chapter XI.).

The arm-rest is useful if the patient is turned partly on his
side ; this may be done provided that the empyema is shut off
from the air-ways and no great quantity of free fluid exists.
The hour chosen for thoracic operations is important. The
abscess or bronchi fill up during the night, and as a rule the
patient coughs for some time in the early morning and clears
his lungs. When he has succeeded in this, the operation should
take place.

Surgery of the heart has been practised more frequently in
the later years of the war. The lessened activity of the heart
and lowering of blood-pressure which occur under chloroform
would appear to be an advantage, so that either this anæs-
thetic or the use of nitrous oxide and oxygen is indicated.*

ANÆSTHETICS IN ABDOMINAL SURGERY.

Complete relaxation of the recti and other abdominal muscles
is imperative ; great quietude and freedom from hurried respira-
tion, coughing, and vomiting, are also necessary for operations
upon the abdominal parietes or viscera. To ensure these con-
ditions, chloroform, the alcohol-chloroform or the A.C.E. mix-
ture, or open ether is suitable. We now have the alternative
methods of ether infusion, intratracheal insufflation, Crile's
anoci-association, and spinal anæsthesia. When a general anæs-
thetic is in use, the patient must be kept fully under it during
incision through the parietes ; subsequently a lesser degree of
narcotism is needed, until the fascial-skin sutures are put in, when
full anæsthesia will again be requisite. Great care must be
taken, however, that the patient is not allowed to recover suffi-
ciently for the supervention of vomiting. In operations upon
the gall-bladder and its ducts, and generally for those in the
region of the upper abdomen, it is often very difficult to effect
complete relaxation of the parietal structures. This difficulty
is partly anatomical in origin, and partly reflex, due to handling

* Sir Charles Ballance, in his Bradshaw Lecture, indicates that the
surgery of the heart involves many operations which, from their nature, call
for anæsthesia. He has used chloroform given by the Vernon Harcourt
inhaler, and tells me, in a private letter, that this has been wholly satis-
factory. See *Lancet*, January 3, 10, 17, 1920, pp. 1, 74, and 134.

of the viscera.   Very commonly phonation, almost like articulate groans, is caused reflexly, and that even when the conjunctival reflex is abolished, the light reflex sluggish, and the pupil contracted.   These must not be allowed to mislead the anæsthetist or induce him to deepen narcosis, and so give an overdose.   In cases in which a large tumour or collection of fluid or gas is removed from the abdomen, and the heart—previously displaced—is allowed to right itself suddenly, there is especial danger of syncope, and precautions against this must be taken. The head should be kept low and a small percentage of chloroform vapour given in order to limit the fall of blood-pressure. Although some surgeons prefer chloroform in abdominal surgery, it is by no means advisable to give it in all cases.   When the patient is much collapsed, or is very feeble, I have found ether with oxygen a much better and safer anæsthetic.   And this view is, I believe, now commonly held by anæsthetists. Certainly with management it is often possible with ether to obtain as good, and sometimes even better, results than with chloroform.   It is necessary that the ether should be inhaled for some time before the operation is commenced, to allow time for complete muscular relaxation.   When the case is very prolonged, care is requisite to avoid too much ether being taken. This is easily accomplished, as, after having been once placed profoundly under ether, the patient requires but little more of the anæsthetic.

The plan I usually pursue is to order a preliminary hypodermic injection of atropine, morphine, and scopolamine, and then to commence the induction with ethyl chloride or nitrous oxide, then give ether, substituting chloroform if the operation is a prolonged one.   This method is also useful in extensive operations upon the kidneys.   In cases of intestinal obstruction it is well to perform lavage before the anæsthetic is administered.

It is the common practice at the present time to adopt an open ether method in abdominal operations, and especially if acute septic infection is present, as it is believed that if chloroform is adopted it may lead to destructive changes in the liver and kidneys and lessen the patient's chances of recovery.   In the face of Graham's work, which appears to show that ether, when inhaled for a long time, lessens or stays phagocytosis and agglutination for some days or weeks, it is well to adopt the precaution of injecting five ounces of pure olive oil into the

bowel as soon as the operation is completed.* This procedure
appears to counteract the effect of ether as regards phagocytosis
and to restore that function within a few hours.

The rigidity of the recti-abdominis muscles—the bane alike
of surgeon and anæsthetist—is very commonly the result of
cyanosis, itself caused by some reflex or other interference with
respiration. Relaxation of these muscles can usually be obtained
by giving oxygen freely with the general anæsthetic. In ex-
treme cases I use ether and oxygen, since ether ultimately
produces greater relaxation than chloroform, and do so even
if I return subsequently to the use of chloroform. A procedure
which assists to lessen rigidity and shock is to combine spinal
anæsthesia with the use of a general anæsthetic, usually ether.
This is valuable in prolonged, complicated operations on the
abdomen and those involving the abdomen and pelvis, *e.g.* re-
section of the rectum. It also has the merit of maintaining
anæsthesia longer than can be expected after an intrathecal
injection of stovaine or other analgesic, also it protects the
patient from psychic shock, such as is inevitable in severe and
prolonged abdominal operations. The technique is a combina-
tion of the methods adopted in spinal and general anæsthesia.

It has been urged that the use of closed inhalers is apt to
provoke rigidity of the muscles by hampering respiration. I
am convinced that such a statement is only partly, if at all,
true. A closed inhaler when properly employed need not cause
any cyanosis. It is only a question of the patient's ability to
fill and empty the bag attached to the inhaler, and any patient
who is not very markedly collapsed will be able to do this easily ;
but if he cannot do so it is probable that he is not in any need
of further anæsthetic. This misapprehension about the use of
closed inhalers has arisen from a faulty method of using them,
and from the practice of admitting insufficient air, and so causing
anoxæmia. The advantage of using a closed ether method
during some parts of the narcosis for extensive abdominal opera-
tions is that it keeps up the required carbon dioxide content of
the blood and prevents the development of acapnia. When
large serous surfaces are exposed it is asserted that serious loss
of carbon dioxide occurs and so acapnia may supervene, a con-
dition which, making for danger as it does, must be kept in mind

* See a useful paper by Dr. Ferguson dealing with this subject, *New
York Medical Journal*, June 29, 1912.

during the management of these trying cases. The adoption of a preliminary scopolamorphine-atropine injection before the general anæsthetic should be routine, as it helps in every way. Before the open ether method it is absolutely necessary. Persons who are collapsed, and whose respiration and circulation are, as the result of disease or surgical shock, in a feeble and almost failing condition, can be stimulated by freely pouring ether upon an Allis' inhaler or even upon a mask. As soon as they improve—and they will do so in a few minutes—ether and oxygen from a closed inhaler can with advantage be substituted, followed, if need be, by chloroform, preferably from a regulating inhaler.

In operations upon the upper abdomen complete relaxation is often difficult. When a block under the back is used it should not be introduced until complete anæsthesia has been attained, and should be withdrawn before the final sewing up of the parietes is attempted. Raising the patient's shoulders and thighs will often relax the muscles and render the surgeon's manipulation easier.

Patients often complain of backache after a prolonged abdominal operation ; this discomfort can be avoided if a small pillow is placed under the " small of the back."

For skin incisions local analgesia may be used, but the subsequent manipulation of the viscera generally causes pain and so may induce vomiting and faintness. To prevent this occurring the use of a general anæsthetic may be required.

In the case of abdominal operations undertaken during extreme shock or when they involve the likelihood of the onset of shock, the infusion ether method offers peculiar advantages. It should, however, be carefully watched, and if too profound narcosis occurs the ether should be very much lessened, or even simply saline should be infused. What has already been said about the danger of excessive stimulation by ether applies especially to this type of case. The intratracheal method of giving ether, and possibly chloroform, is of value in abdominal surgery as the respiratory movements are lessened to a minimum. In any case, the vapour of the general anæsthetic should be warmed before use in abdominal surgery so as to lessen the shock incident to such procedure. The nitrous oxide and oxygen mixture, with an occasional addition of ether, is extolled by some anæsthetists. It gives less relaxation than other methods (see p. 121).

In the **radical cure** of **hernia** and **inguinal colotomy,** ether
answers perfectly well. Both these operations can in some cases
be done under local analgesia, but not if the patient is timid
and liable to shock.

Dr. Crile's system, described on p. 350, is of great value in
abdominal surgery.

Spinal analgesia supplies an alternative method for operations
on the lower abdomen and pelvis, and is preferred by some
surgeons for emergency operations such as acute strangulation
of the intestine and obstruction. In this last condition, however,
the same danger of fæcal drowning is present as when a general
anæsthetic is given, and deaths from this cause have been re-
corded even though spinal injection had been practised.

In cases of " acute abdomen," spinal anæsthesia is said to prove
especially valuable. The patient's severe pain is at once relieved,
the splanchnic reflex-inhibition is removed and muscular relaxa-
tion obtained. The intestines recover so much of their tonus
as to release flatus, and frequently defecation occurs, stasis
being overcome. The effect of this is that, when the abdomen is
opened, there is less liability to extrusion of greatly distended
intestines, and the operative measures are rendered less difficult.*

Intestinal Obstruction.

The methods in most common use for obtaining anæsthesia
in this condition are : (1) the employment of a general anæs-
thetic ; (2) spinal analgesia ; (3) local analgesia.

(1) In view of the fact that the main danger arises from
regurgitation of the contents of the stomach and intestines as
soon as the tonus of the muscle at the cardiac and pyloric orifices
is lessened by the anæsthetic, it is best to adopt lavage before
the anæsthetic is commenced. Some patients are too feeble
to allow of this, and even after lavage fresh regurgitation is
liable to occur, so that a light narcosis is essential to preserve
the laryngeal reflex. The patient's shoulders and head should
be placed rather high. In extreme cases the initial incisions
can be performed under local analgesia, general anæsthesia being
adopted later when manipulation of the abdominal viscera is

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* See a paper on " Spinal Anæsthesia, with Special Reference to the
Acute Abdomen " by Mr. P. P. Cole, *Lancet*, Oct. 7, 1916, p. 645 ; and a
letter on the same subject by Mr. J. Morley, *Lancet*, Oct. 21, 1916, p. 728,

taking place. The plan * I have suggested, although it involves
the extra risk of performing a preliminary laryngotomy, safe-
guards the patient from fæcal drowning. It consists in giving
the anæsthetic by a laryngotomy opening after completely
blocking the upper opening of the air-ways by careful packing
and the introduction of a double stomach-tube through which
that viscus is irrigated continuously. The laryngotomy can
be done under local analgesia ; the packing must be carefully
and thoroughly carried out.   The adoption of intratracheal
insufflation would appear to be an excellent substitute for this
plan, except there is a danger lest stercoraceous material should
become aspirated during the preliminary inhalation anæsthesia,
which is usual before the catheter is introduced into the
trachea. With regard to (2) and (3) no detailed description is
needed as either method is conducted on routine lines (see
Chapter XI.).

PELVIC SURGERY.

For the usual gynæcological operations nitrous oxide with
oxygen or ethyl chloride given alone in very brief cases, or
followed by ether for longer ones, may be used. The lithotomy
position, especially in obese subjects, sometimes gives rise to
respiratory embarrassment and circulatory depression which may
produce faintness or syncope. I know of one case at least in
which breathing ceased and the patient was only restored by
being placed horizontal while artificial respiration was performed.
Mr. C. J. Bond † (of Leicester) has advanced reasons for believing
that the displacement of the heart due to posture produces
marked circulatory changes. It is probable that the lithotomy
position may cause some dislocation of the heart, and that
the syncope arising from this posture is due as much to inter-
ference with the heart's action as to embarrassment of respira-
tion.

Operations about the bladder, such as prostatectomy, require
thorough relaxation to enable the surgeon to introduce his fingers
into the bladder. This can be obtained by spinal anæsthesia,
although this method is not suitable for all cases. It can be

* _Brit. Med. Jour._, April 23, 1910 : " Fæcal Vomiting during Anæs-
thesia, a suggested method of obviating its danger."

† _Ibid._, Dec. 12, 1885.

usefully supplemented by giving a general anæsthetic, *e.g.* nitrous oxide and oxygen, to stave off psychic shock.

If a general anæsthetic is decided upon, the nitrous oxide or ethyl chloride-ether sequences are suitable, but should be preceded by a hypodermic of scopolamorphine and atropine, and given with warmed oxygen. It is imperative that the patient should be thoroughly relaxed *before* the operation is commenced. If this is not done, spasmodic contraction of the muscles may occur, which is very difficult to overcome when once established. At the time that the prostate is being dragged from its bed serious shock is likely to occur, so that in feeble subjects it is best to give ether after complete relaxation has been obtained.

The Trendelenburg position, used both in abdominal and pelvic surgery, will sometimes give rise to difficulties somewhat similar to those which occur in the lithotomy posture. When the diaphragm is forced up, especially in the case of short, stout persons, duskiness with embarrassed breathing and cardiac distress may arise.* These should be watched for, and the position corrected before more dangerous symptoms arise. In feeble, anæmic subjects, the head-down position is often distinctly helpful, but in these, as in all cases, great care is necessary to avoid any jerk or suddenness in altering the relative positions of the poles of the patient's body.

Rectal Surgery.

All operations about the anus and rectum are not only very painful, but may excite reflex straining, spasm, and respiratory embarrassment. In anæsthetising for such operations, profound narcosis is needful. The sequence of gas and ether in most cases answers well, although it is necessary to give enough ether to induce absolute muscular flaccidity, snoring respiration, and widely dilated pupils—and, further, to maintain deep narcosis to the end of the operation. Most authorities regard ether as the safest agent for these cases, since less reflex shock arises under it than under chloroform. The patients are commonly anæmic and in feeble health, and need much care and watchfulness.

In such severe operations as Kraske's there is commonly a

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* Mr. Carter Braine has recorded a case in which œdema of the face became developed as a result of the inverted position.

marked fall of blood-pressure, so that the pulse should be kept under observation. The posture, the loss of blood, and the shock render these operations especially anxious ones for the anæsthetist. It is necessary to decrease the amount of anæsthetic given when the hæmorrhage causes material shock. Many rectal operations can be advantageously performed under spinal anæsthesia. Although it is theoretically possible to operate using local analgesia, yet the procedure is so complicated and unpleasant to the patient that this plan is seldom adopted in this country.

In Cases of Pre-existing Disease.

It is frequently desirable to employ ether for patients who suffer from bronchial or other disability, and this can be done
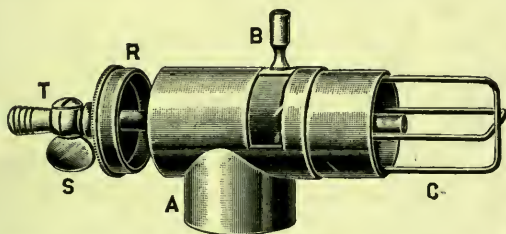
Fig. 80.—Dr. Beresford Kingsford's moist-air and ether apparatus.

with success, provided the cases are carefully chosen and due precautions taken. As pointed out above, the intratracheal method can frequently be adopted.

Dr. Kingsford has introduced a method of giving ether in cases in which there is a tendency to asthma and bronchitis, and this has proved of signal service. It is applicable for patients subject to bronchitis or asthma, but not actually suffering from either of these in an acute form at the time of anæsthetisation, and when chloroform appears for some reason to be undesirable the apparatus shown in fig. 80 may be used with advantage.

A fits a wide-bore inhaler, such as (the late) Sir F. Hewitt's. A wide-neck reversible Ormsby bag is attached over C by a thick rubber band.

R fixed to T is pushed home into A for use.

B opens a window in the attachment and cuts off the bag to any desired extent.

T admits "gas," oxygen, or ethyl chloride, whatever the position of B.

For the gas-ether sequence in cases of bronchitis, B is closed and a little hot water poured into the bag through A ; B is then opened, and nitrous oxide, with or without oxygen, is allowed to enter the bag through T.

The apparatus thus fitted up is now applied to the patient's face with B open. After a breath or two B is closed, and the patient breathes warm and moist nitrous oxide. After three or four more breaths ether is turned on gradually but rapidly, and induction completed in from two to three minutes.

Not more than about $1\frac{1}{2}$ fl. oz. of ether need be used, and, as a rule, this will not provoke any coughing or struggling.

During the operation B is always more or less open, so that *with every breath* the patient gets *some fresh air*, and that as warm and moist as seems advisable.

The hot water in the bag can be easily renewed, or the bag may be allowed to float in a bowl of hot water.

Both mount and bag can be boiled ; there are no valves to get out of order.

The mount fits Hewitt's face-piece, and so can be employed for ethyl chloride, that anæsthetic being sprayed into the bag through T, B being left open until the mask is applied to the patient's face.

At this stage B is gradually closed, thereby opening the bag.

By means of an "adapter" A may be adjusted to any form of Clover's inhaler or face-piece.

This warm and moist-ether method has been used in a great number of abdominal cases of every kind, from gall-stones to Wertheim's, and in several brain cases in which ether was employed. It has always proved satisfactory.

Occasionally one-sixteenth part of chloroform is useful for the induction ; or, *temporarily* during operation, to get quicker relaxation of the abdominal muscles.

As the description shows, the apparatus fulfils the requirements of a warmed moist-ether vapour method so essential for the type of cases indicated.

ANÆSTHETICS IN OBSTETRIC PRACTICE.

Choice of anæsthetics; stage when to be administered.—As a rule chloroform is commonly employed, and is considered to be preferable to ether. When an obstetric operation is to be performed, or when the patient is greatly depressed by hæmorrhage or shock, and when it is desired to promote uterine contraction, ether may be selected. Chloroform is preferable in eclampsia and in cases of retained placenta. The A.C.E. and alcohol-chloroform [A.C.] mixtures also answer admirably. Otis, of Boston, employed in obstetric practice a mixture of ethyl bromide 1 part, chloroform 3 parts, and alcohol 4 parts; of this preparation he speaks highly. However, ethyl bromide is a dangerous agent and had better be avoided.

Alternative methods of producing painless delivery are (*a*) the use of alkaloids (see below, "Twilight Sleep," p. 391); (*b*) so-called "analgesia" or drowsing by nitrous oxide and oxygen, given usually after alkaloids; (*c*) local analgesia; (*d*) spinal or sacral anæsthesia.

NITROUS OXIDE AND OXYGEN IN PARTURITION.

Dr. A. E. Guedel * describes this method as superior to those more commonly employed. He advises mixtures of 65 volumes of nitrous oxide with 35 of air; or 82 volumes of nitrous oxide to 18 of oxygen. Narcotics are given in the first stage, as, if employed later, morphine depresses the respiratory centre. When pains are excessive ether is relied upon to abrogate them at the time of expulsion of the child. Drowsing rather than unconsciousness is aimed at, so that care has to be taken that the full anæsthetic affect of the nitrous oxide is prevented. As

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* "American Year Book of Anæsthesia and Analgesia," 1915, p. 227.

little or no relaxation of muscles occurs with nitrous oxide, the perinæum is more frequently torn when it is used than when one of the more powerful anæsthetics is inhaled. To obviate this infiltration of the perineal structures with novocain is practised. The persistence of muscular tonus, it is asserted, possesses advantages. The full expulsive power of the uterus is conserved so that ergot is not required, and as the mother is semiconscious, she can bear down and so assist her labour. However, it must be remembered that the uterine muscular fibres are only affected by very large quantities of chloroform, since that anæsthetic relaxes voluntary muscles very much more readily than unstriped muscle. Dr. Guedel finds that women drowsed by his method respond to " suggestion " quite readily. He further is led from his experience to believe that the mother and babe are less " upset " by nitrous oxide than by chloroform. The breasts fill rapidly with milk and the child is free from intestinal pain. Death under nitrous oxide is due to asphyxia, acute cardiac dilatation, or to apoplexy, and so the method is excluded for persons whose respiratory or cardio-vascular systems are not sound. The fact, now recognised, that during pregnancy the maternal heart is always dilated would appear to call for caution in the adoption of this method. As to the statement that ergot is not called for, it would seem that those who advise the use of nitrous oxide in labour overlook the fact that a uterus which fails to contract in the late stages of labour, probably does so through muscle exhaustion, and not through anæsthetic drugging. Unless the utmost care is taken to avoid anoxæmia due to continuous inhalation of nitrous oxide, there is a danger of asphyxia and the incident irregular and violent contraction of muscles with increased blood-pressure, all of which are undesirable and often dangerous during labour. Dr. Guedel's statements about the ill effects of chloroform in parturition are not consonant with the experience of most obstetricians. Dr. C. H. Baird,* in the course of an experimental and clinical study, found that prolonged inhalation, whether of nitrous oxide and oxygen or of chloroform, proved more dangerous to the fœtus than did ether. Although prolonged inhalation of nitrous oxide and oxygen was dangerous to the fœtus, causing tissue asphyxia, yet if given intermittently and for a brief time only and in short spells

* " Surgery, Gynæcology, and Obstetrics," Feb. 1918.

during the commencement of uterine contractions, it produced no bad effects.

Mr. C. T. W. Hirsch has elaborated a technique. The first necessity is a reliable apparatus, the Teter as modified by Gwathmey answers well. Mr. Hirsch either uses one described by Marshall or the apparatus he has himself suggested.* When an ordinary face-piece is adopted, the patient places it on her face as a pain comes on and depresses the handle on the apparatus which admits the gases. As she becomes drowsy (analgesic) her fingers relax and the handle springs back, cutting off the supply of gases. The process is repeated as pains recur. Instead of a gas-bag which would need the attention of the accoucheur to cut off the anæsthetic, a governor is fitted to the cylinder which comes into action as soon as the handle is released and so cuts off the gas-supply at the source.† If rebreathing is employed a slightly more complicated system becomes requisite. The method has many advocates in the United States of America and in Canada, but has not been generally adopted in Great Britain.

The employment of spinal and of sacral anæsthesia, except in some few complicated cases of labour, has not received sufficient attention for any authoritative statement to be made upon the merits of the methods. The technique in either case is described in Chapter XI.

The Use of Chloroform or Ether.

Snow advised that chloroform should be withheld until the *os uteri* is fully dilated and well-marked expulsive pains have appeared. He, however, made an exception to this rule when, during an earlier stage, the pains were very severe. When there is a spasm of the cervix, if chloroform is given in the first stage for 20 or 30 minutes, the spasm relaxes and the pains, which were very severe before, become easier ; as the patient recovers from the anæsthetic, labour is accelerated.

Spiegelberg extols the employment of an anæsthetic for neuralgia and cramps occurring during parturition.

In normal labour little chloroform is needed ; if a very dilute

* *Lancet*, July 13, 1918.
† The apparatus is made by the Dental Manufacturing Company, Alston House, Newman Street, W.

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vapour is inhaled the patient sinks into a quiet sleep, and her sensibility to pain is lessened. The second degree (Snow) of narcosis is quite sufficient for ordinary cases, and, so far as I know, no danger from ventricular fibrillation has been reported as a result of this light anæsthesia. The uterine contractions are but slightly lessened by the anæsthetic. Although during the pains the woman may groan and appear restless, her complaints are but slight, and as soon as the pain passes off she again falls asleep.

Rules guiding the administration :—

1. Quietide in the room is essential ; fresh air should be admitted from time to time, and the patient's posture should be unconstrained.

2. Chloroform should be commenced when the labour is in its second stage if the pains are very acute, but if they are not it is best to wait until the fœtal head is on the perinæum. As a rule the chloroform should not be given during the intervals between the pains, unless the severity of the pains is very great, or it is deemed advisable to induce deep anæsthesia for the performance of an obstetric operation.

3. For nervous women and those who dread pain, also in cases where the perinæum is very rigid, chloroform should be used, to relax the perineal structures.

4. In the event of the patient becoming excited, the chloroform should be pushed to full anæsthesia whenever it is deemed necessary for the woman to be anæsthetised.

5. In protracted labour, when the patient is to be kept anæsthetic, it is better to intermit the inhalation, to avoid an injurious accumulation of the drug.

6. Deep anæsthesia must be obtained when an obstetric operation becomes necessary (Charpentier).

7. The advisability of giving an anæsthetic to a woman in labour when cardiac, pulmonary, or renal disease exists, must be determined by the same general principles which guide us in similar circumstances when coming to a decision for surgical cases.

8. It is necessary to carefully guard against over-distension of her bladder when the patient is kept wholly or partially under an anæsthetic.

9. It is inexpedient to awaken the patient to consciousness by artificial means, *e.g.* slapping with a wet towel.

10. When the fœtal head bears on the perinæum, the anæsthetic should be given more freely, as it relieves the increased pain, and also relaxes the maternal passages, while it lessens the probability of rupturing the perinæum.

11. Should the patient be depressed or the pains become sluggish during the administration of an anæsthetic, an occasional stimulant may be administered. This practice should be confined within narrow limits, and when pursued, sal volatile in water is the best stimulant to employ.

12. If the anæsthetic appears to interfere with the progress of labour, it may be necessary to suspend its use for a time and readminister it after an interval, or even to withdraw it altogether. Chloroform is best avoided if a meal has been recently taken, since the vomiting which is likely to follow will impede delivery.

Objections.—These, although strenuously urged by some, are probably more theoretical than real.

1. Chloroform is said to increase the mortality alike among mothers and children.

Statistics certainly negative this statement. It has been shown that the danger to the parturient is *ceteris paribus* in direct proportion to the amount of pain experienced, and since chloroform minimises the pain, it lessens the actual danger of childbirth.

2. It is asserted that it protracts the labour.

Dönhoff * gives the results of his researches with the toko-dynamometer. Light narcosis under chloroform lessened, but deeper narcosis abrogated, uterine contractions. Hence, chloroform is the best anæsthetic in cases of threatened rupture of the uterus with transverse presentation and loss of amniotic fluid.

Deep narcosis renders the voluntary abdominal muscles lax, and so interferes with expulsive efforts. *Very deep narcosis* also paralyses the uterine muscular tissue. On the other hand, a womb, exhausted by frequent and ineffectual contractions, will often regain tone under chloroform and resume vigorous expulsive movements.

* *Arch. f. Gynäkol.*, Bd. 42, p. 305.

3. Rupture of the perinæum is said to be more frequent when chloroform is used, but both experience and *a priori* reasoning point to the reverse being true, since under chloroform the violence of the expulsive pains is lessened and the perineal structures are relaxed. The fact that, in cases of rigid perinæum, chloroform is given may account for the statement. The present practice is to produce deep narcosis in such patients with the express view of saving the perinæum.

4. Complications are asserted to be more liable to occur when an anæsthetic is used.

This point was carefully investigated by the Chloroform Committee of the then Royal Medical and Chirurgical Society, and it was found that chloroform, when properly administered, does not predispose to inflammation, puerperal convulsion, apoplexy, or other mishap.

Opinions differ as to whether it predisposes to imperfect contraction of the uterus and so to *post-partum* hæmorrhage. The answer to this question depends, first on the degree of narcosis arrived at, secondly on the length of time allowed to elapse before its use, and thirdly on the duration of its employment and especially after the birth of the fœtal head. It is also highly important that the patient's respiration should be free and unhampered by her posture. Lactation is not injuriously affected, nor is the child in any way injured.

Convalescence, so far from being delayed, is actually accelerated by the use of chloroform in childbirth. This is probably explained by the fact that when an anæsthetic is used the nervous system is protected from shock (Sansom).

Method of exhibition. — When chloroform is employed the open method is simplest, admitting as it does plenty of air. A little chloroform may be sprinkled on cotton-wool in a glass tumbler, and the patient allowed to hold this, so that when she grows drowsy the improvised inhaler drops from the hand. Care must be taken, if lint or a towel is used, that the face does not fall over the chloroformed cloth, or the breathing become impeded by the pillow or bedding. The Vernon Harcourt inhaler is excellent in labour. The body of the instrument is hung over the back of the bed and the face-piece connected with it by a length of flexible tubing. The patient holds the mask over her face as long as she is conscious, and as soon as her grasp relaxes the mask falls away from her.

" When deep anæsthesia is required it is best to have a skilled administrator " (Chloroform Committee, Roy. Med. and Chir. Soc.).

When chloroform, or the A.C.E. mixture, is administered by a person who gives himself up solely to this duty, the use of the Vernon Harcourt regulator, or of Junker's inhaler fitted with the glass mask (see pp. 250 and 263), has the advantage of allowing less escape of vapour into the room, so that the air is kept more pure. This is especially important when the chamber is lighted by gas or oil lamps (see p. 306).

In the First Stage of Labour, chloroform or the A.C. mixture, if required at all, should be given intermittently and in small quantities, except in the case of spasm of the cervix, when complete narcosis is needed. As a rule the first degree of narcosis is deep enough. The patient is conscious, but only slightly conscious of painful sensations. If any excitement and struggling occur, the patient must be allowed to recover her self-control. Some persons need more chloroform than others, so that the administrator must decide each case on its own merits, and further must be guided by his own observations, and not be influenced too much by the patient's cry of " Give me some more." Women frequently repeat this phrase when hardly conscious, and are unaware of preferring any request. However, if chloral hydrate in grs. 15 until 30 to 40 grs. have been given in the first stage, the amount of chloroform required later on will be small.*

In the Second Stage, chloroform should be given only during the pains, and then merely to light narcosis, since the woman needs the use of the abdominal muscles. At the stage of labour when the head is traversing the perinæum, deeper narcosis is needed to relax the soft parts, whilst at the last, as the head emerges through the vulva, chloroform should be freely administered.

When Instrumental Procedure is requisite, deeper narcosis is needful, and especial caution is required in order to prevent the patient being made simply excited and her muscles rigid— a condition alike dangerous to the mother and to the child. In

* When chloral hydrate has been given in the first stage, caution must be practised if chloroform is administered later. If the patient is drowsy and obviously still under the influence of the chloral hydrate, very little, if any, chloroform should be used.

this stage the narcosis must be deepened and true anæsthesia obtained.

OBSTETRIC OPERATIONS.

For *Version* and instrumental deliveries, if an anæsthetic is employed, full anæsthesia is requisite and may be obtained either by chloroform, the A.C. mixture, ether, or by nitrous oxide and oxygen. In deep narcosis from chloroform the parturient is probably placed in the same danger of overdosage as when anæsthetised for any surgical operation. Many practitioners employ the A.C.E. mixture in all their obstetric cases, and give it from a cone or Rendle's mask. Ether, until the introduction of the open mask, was but little used in this country in obstetric surgery. It is sometimes urged against it that it does not relax the uterine tissue so effectually as chloroform, but this statement is open to question, since profound etherisation does produce relaxation. And further, if this objection is valid it tells also the other way, as under such circumstances hæmorrhage would be less likely to be severe. The ether effect, moreover, passes off more rapidly.

For extraction by forceps narcosis sufficiently deep to keep the patient quiet is needed. Some authorities prefer the use of ether in these cases.

Craniotomy—Hour-glass contraction—Retained placenta.— In these cases complete relaxation is necessary, but as the patient is often very collapsed, great care has to be taken that the anæsthetic is not unduly pushed.

Puerperal convulsions.—Chloroform was formerly used in all cases of convulsions associated with labour. It is, however, contra-indicated in apoplectic seizures. The modern practice is to use morphine, hot-air baths, etc., and only to give chloroform if other means fail. It is believed that very prolonged inhalation of chloroform produces a deleterious effect upon the patient.

AFTER-EFFECTS.

After prolonged chloroformisation dryness of the mouth and throat and great thirst are sometimes complained of, and can be relieved by sipping hot water and wiping the tongue with

glycerine and borax, or by sucking thinly sliced lemon. Vomiting is rare; faintness, excitement, and headache have sometimes been manifested, but as a rule few unpleasant results follow the use of chloroform in childbirth.

The Twilight Sleep Method (Gauss's "Dämmerschlaf" System).

It is now some years since Dr. Karl Gauss of Freiburg suggested his system of lessening the pangs of childbirth by the use of scopolamine and morphine. The condition which Gauss terms " dämmerschlaf " or twilight sleep is obtained as follows :—

Two separate sterile solutions are prepared ; one a 0·03 per cent. aqueous solution of crystalline scopolamine hydrobromide, and the other a 1 per cent. aqueous solution of morphine.

When the pains recur about every five or six minutes, and persist for thirty seconds, the woman is given a hypodermic injection of 1 to 1·5 c.c. of the solution of scopolamine hydrobromide (*i.e.* 0·30 to 0·45 milligramme), with 1 c.c. of the morphine solution (*i.e.* 0·01 gramme). Half an hour after this the woman is shown some familiar object, such as a pair of scissors or a skein of wool. In another half-hour she is questioned as to whether she remembers the object, and if she does not she is considered to be in a satisfactory condition (dämmerschlaf). This testing is continued at intervals, and according to the response the patient has or has not further injections. Such injections should be 0·5 c.c. to 1 c.c. of the scopolamine solution ; the morphine is not repeated as it interferes with the expulsive power of the uterine muscle. As a rule four injections suffice, given at intervals of an hour. About 0·75 milligramme is an average of the *total* amount of scopolamine required, although much less will often suffice.

During the carrying out of the method the utmost quiet is enjoined ; Gauss even insists upon blocking the ears of the patient with cotton-wool. The common causes of failure are (1) commencing the injections too early ; (2) giving them too rapidly and in too large doses ; (3) giving the injection at too short an interval before the birth. The dangers are—interference with the expulsive power of the uterus, the onset of hallucinations, and restlessness, all due to overdosage.

Scopolamine may weaken the heart if given in excessive

doses, and so Dr. Abbott of Chicago adds cactina to the injection
to obviate this. However, the value of this drug as a heart
stimulant is not universally acknowledged. In some cases the
child appears to suffer : its breathing is slow, and cyanosis and
heart-feebleness appear. After delivery, as well as during the
period of preparation, the woman needs constant and most
careful watching, and the same care is needed for the infant
until the effects of the drugs have passed off. Dr. Gauss re-
affirmed his belief in the safety and value of the method before
the Seventeenth International Congress (Subsection of Anæs-
thetics) in 1913.

In this country Dr. Ayres of Stourbridge, and Dr. Giuseppi
of Felixstowe, amongst others, have practised this system, and
have expressed their satisfaction with it. It may be pointed
out that although scopolamine and hyoscine are closely allied,
yet they are not pharmacologically interchangeable—indeed,
scopolamine appears to differ in its physiological behaviour
according to the source from which it is obtained, so that it is
essential that reliable samples should be obtained.

It is not possible to arrive at the danger-rate to mothers and
babes when the twilight sleep method is pursued. It is certain,
however, that relegating the injections and the after-care of
patients to unqualified persons adds greatly to the risk. British
obstetricians, after considering the question collectively, came to
the conclusion that the plan was useful in some picked cases,
but does not possess a wide field of application and is not free
of danger. The amnesia, even if it is present, as it is claimed to
be, in parturition during twilight sleep, does not necessarily prove
that pain has not been experienced during the labour. Dr.
Herbert Spencer * writes : " The truth is that ' twilight sleep '
is not painless labour, and involves increased risk to mother and
child."

* _Lancet_, April 1918, p. 515.

CHAPTER X.

THE COMPLICATIONS, ACCIDENTS, AND AFTER-EFFECTS OF ANÆSTHESIA: THEIR PROPHYLAXIS AND TREATMENT.

Shock.—Hæmorrhagic Diathesis and Hæmorrhage, diseased states such as Lymphatism, Graves' Disease, Angio-neurotic Œdema produce effects upon the patient which render him especially liable to complications during anæsthesia. It is proposed to deal with these before considering the more common complications and accidents incident to narcosis.

Shock.

This state, although difficult to define, is easily recognised clinically, by pallor, feeble respiration, lowered temperature, restlessness or intense hebetude, and a weakened pulse, although these symptoms vary according to the degree of shock present. In extreme cases it is often termed "collapse."

Surgical Shock in War Surgery is known as **Wound Shock** (Cowell). It may be regarded as a reaction to trauma (Bazett). In lighter degrees of shock the pulse is accelerated, pulmonary ventilation is increased by rapid and deep breathing, there is a heightened blood and pulse pressure, while the blood volume is enlarged and metabolic activity promoted. As a concomitant of this last, secretions, such as the output of adrenalin, are more abundant. In severer degrees of shock the nerve-centres become exhausted. It is this exhaustion which renders shock a danger to the organism.

Since in trauma, especially when hæmorrhage coexists, there is a tendency to lessened blood-supply to the tissues, lessened oxygenation, and to interference with metabolism, the minor degrees of shock may be regarded as protective, because in them there is increased blood circulation and a better air exchange in

the lungs ; while in severe degrees shock is protective in so far as the weakened circulation checks hæmorrhage.*

If this reaction to trauma fails to restore the patient to the normal or an approximation to it, the effects of fatigue, and ultimately the exhaustion of the nerve-centres, supervene. The pulse is then slowed, blood and pulse pressure (*i.e.* the difference between the systolic and diastolic blood-pressure) is lowered, the blood tends to become more concentrated and metabolism is decreased. This last event leads to fall of temperature, and renders the patient peculiarly susceptible to the effects of cold, one, if not the chief, danger of this state. The increased output of adrenalin, which at the first tended to increase cardiac activity, to lessen peristalsis, to diminish the coagulation time of blood, and to liberate glucose from the liver into the circulation, in the later stages of reaction probably leads to increased shock through over-stimulation and exhaustion.

In **wound shock** the following epiphenomena have been observed : Arterial hypotension ; capillary stasis and increased permeability of the walls of the blood-vessels ; reduction of the blood volume, which is consequent upon hæmorrhage, and the escape of fluid from the blood-vessels ; absorption of toxic products, possibly also the result of toxæmia from hypersecretion of adrenalin ; diminished intercellular oxygénation (tissue asphyxia), with damage to the nerve tissues ; acidosis ; lowering of body temperature ; poisoning by the action of some anæsthetics ; the effects of hæmorrhage.†

Wound shock may be primary, when it appears immediately, or secondary, in which case its symptoms develop after the lapse of some hours.

Shock, whenever present, complicates anæsthesia, hence the anæsthetist should be familiar with it in order to counteract its baleful effects on the patient. In civil practice we have to recognise that shock may be due to (i) pre-existing disease, as, for example, collapse following the rupture of a duodenal ulcer; (ii) injury or accidents involving grave damage to the tissues,

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* See article on " Shock and Hæmorrhage," by H. C. Bazett, M.C., Capt. R.A.M.C., in *Manual of War Surgery*, by Seymour Barling and J. T. Morrison, pp. 397 *et seq.*

† Arris and Gale Lectures on "The Initiation of Wound Shock and its Relation to Surgical Shock," by E. M. Cowell, D.S.O., M.D., F.R.C.S., *Lancet*, July 26, 1919.

e.g. motor smashes. To these we must add another cause, viz.
(iii) shock the result of an anæsthetic. During a surgical opera-
tion several of the factors producing shock act together, and every
effort has to be made (*a*) to ameliorate ante-operation shock ;
(*b*) to lessen shock occurring during the performance of the
operation ; and (*c*) to prevent the anæsthetic producing further
exhaustion of the central nervous system either at the close
of the operation, or upon the patient's recovery from the imme-
diate effects of the anæsthetic.

Although, in civil practice, anæsthetists are seldom called
upon to administer anæsthetics to patients in a state of shock
such as is constantly met with in war, yet a little consideration
will reveal the fact that shock conditions, whether arising
through the stress of war or in serious bodily depression incident
to disease or surgical trauma in civil life, are closely allied, and
differ, in so far as any difference exists, in degree rather than
in kind.

Death from pure shock may occur, although it is rare. Cowell
insists : " In the cases of shock met with in the practice of
civil surgery, there are almost invariably factors of severe tissue
trauma, toxæmia, hæmorrhage, or psychical disturbance present,
which our study of wound shock has shown to play such an
important part in the initiation of the condition." In war surgery
the patients usually possess the assets of youth and physical
fitness, which are so often denied to the patients upon whom
operations involving great trauma have to be performed in
civil practice. In the latter case, the presence of pre-existing
heart weakness may cause death from shock pure and simple ;
and this has to be kept in mind, since the patient who suffers
from extreme shock may recover if his heart has not lost its
vigour, but may die if his heart is antecedently diseased.

In the present connexion we propose to examine psychical
shock, *i.e.* the result of excitement, fear, or other emotional
states.

Apprehension, or any strong emotional disturbance indepen-
dently of trauma, hæmorrhage, or other objective cause, may
produce fall of blood-pressure inducing psychic shock. It is
sometimes met with in spinal anæsthesia when no pain is ex-
perienced, although **fear of pain** exists. In pre-anæsthetic
days, death from psychic shock was not infrequent, often oc-
curring before the operation had been commenced. Apprehen-

sion of the anæsthetic will occasionally produce some degree of minor shock, and such a condition is the worst in which to embark upon anæsthesia. Every effort should be made to dispel fear and nervousness before the inhalation by cheerful re-assurance, and to avoid fussy preparation performed with gloomy intentness such as will arouse the worst forebodings in the patient. In the early stages of the induction, much can be done to reassure the patient, while the utmost endeavour must be made to induce him to feel that every effort for his welfare is being made, and that his welfare is the sole preoccupation of those engaged in carrying out the steps of the operation. The use of scopolamorphine, antecedently to the general anæsthetic, lessens or abrogates this psychic shock.

Lowering of arterial tension and capillary stasis, with increased permeability of the vascular walls.—It has been pointed out above that in the initial stage of shock a quickened pulse is associated with a rise in arterial pressure, and this condition is succeeded, if shock increased, by a lowering of the pressure and enfeeblement of the heart-beat. In 1893, Mr. J. D. Malcolm * pointed out that in the vascular changes of shock, fever and sepsis are similar and marked by vaso-constriction, thus contesting the assumption that, owing to paralytic dilatation of the capillaries, the blood drained through them and stagnated in the large veins of the splanchnic area. The evidence of post-mortems, as well as that gained during operations upon the abdominal viscera, supports this contention. Vaso-constriction, according to Malcolm, is due to the action of the central nervous system. It is matter for regret that these views cannot be discussed in this book, as they fall rather within the purview of the surgeon and pathologist than in that of the anæsthetist.

It is not proposed to discuss in this place the reasoning which leads to the belief that capillary stasis exists in shock ; that

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* "The Physiology of Death from Traumatic Fever." See also valuable papers by Mr. Malcolm dealing with this subject : " On the Condition of the Blood-vessels during Shock," *Transactions of the Medico-Chirurgical Society*, 1908, vol. xc. ; " The Nature and Treatment of Surgical Shock," *Transactions of the Medical Society of London*, vol. xxxii. ; " The Prevention and Treatment of Shock," *British Medical Journal*, Sept. 17, 1910 ; " On the State of the Blood-vessels in Shock," *Lancet*, Nov. 8, 1913 ; " Discussion on Shock," *Transactions of the Seventeenth International Medical Congress of Medicine in London*, 1913 (section iii).

it does so is contended by Cowell and others who regard it as a definite factor in shock. Cowell has pointed out that hypotension is the result of hæmorrhage, pain, cold, or toxins. Among these we must include certain anæsthetics given by certain methods. This last factor is dealt with below.

Increased permeability of the vessel walls leads to concentration of the blood. Sherrington and Monkton have found that in shock the specific gravity of blood is increased, and Marshall has demonstrated that the percentage of hæmoglobin is raised in shock, and this has been confirmed by Cannon and Fraser. In estimating the value in treatment of intravenous injection of saline, this increased permeability must be remembered, since it is obviously useless to introduce fluid into the circulation if it will at once escape into the perivascular tissues and invade the serous cavities. This escape of fluid from the vessels further leads to a **reduction** in the **volume of the blood.** Where hæmorrhage is present, it is, however, the main factor in its causation. This reduction of the blood's volume has been studied by N. M. Keith and O. H. Robertson. The latter has shown that fluid introduced to maintain the normal circulation is best absorbed when the blood-pressure is low, and such fluid is better introduced by the mouth or rectum than by the intravenous route.

Diminution of oxygenation of the tissues (tissue asphyxia), when persisting for more than a short time, causes destruction of the finer nerve fibrils. Fall in blood-pressure leading to lessened transport of oxygen can be borne up to a certain point, and this point is somewhere between 70 and 80 mm. of mercury. Further, this fall of blood-pressure may be tolerated for an hour, but if it is lowered to 60 mm., evidence of marked shock develops and oxygen starvation occurs (acidosis). After hæmorrhage, owing to the loss of hæmoglobin incident upon the depletion of the corpuscles, decreased tissue oxygenation rapidly supervenes. In the absence of the necessary number of oxygen-carriers, even if the circulation and respiration are effective, giving oxygen inhalations fails, since the plasma can only take up 2 per cent. of oxygen ; so in this case blood transfusion offers the only chance of resuscitating the patient.

Acidosis.—The significance of **acidosis** in shock and similar conditions has to be carefully considered, since its presence, both in military and civil practice, serves as an indication of

the gravity of the shock present. Acidosis * is the condition
in which the alkali reserve is reduced. Normally, sodium bi-
carbonate (an alkali) and carbonic acid (an acid) exist in the
blood. The proportion between these determines the " acidity,"
i.e. the hydrogen-ion concentration. The degree of acidity
can never be greater than that of a saturated solution of carbon
dioxide, nor can the degree of alkalinity exceed that of a weak
solution of sodium bicarbonate. Greater alkalinity than this
stops physiological functions, so, inter alia, the heart will cease
to beat. If some acid, stronger than carbonic acid, e.g. lactic
or diacetic, is produced through perverted function of the tissue
cells, it combines with some of the sodium bicarbonate, liberating
carbon dioxide. When the respiratory centre is normally ex-
citable, the pulmonary ventilation will be increased in these
circumstances and the excess of carbon dioxide eliminated from
the blood, and equilibrium will be re-established. Further, it
must be remembered that the only free acid in the blood is
carbonic acid. Thus, normally, although the actual amount
of sodium bicarbonate (alkali reserve) is decreased by its com-
bination with the fixed acid, yet this is compensated for by the
increased elimination of carbon dioxide from the blood. How-
ever, morphine, chloroform, or ether in excess, lessens the ex-
citability of the respiratory centre, hence the increased elimination
of carbon dioxide by the lungs, necessary for compensation,
may not occur, and as a result a slight increase of acidity in
the blood occurs. To put it more correctly, the normal degree
of alkalinity of the blood in these circumstances is lessened.
This alteration in the reaction of the blood in itself is of no im-
portance, except as an indication that a profound derangement
of the biochemical processes has occurred. The cause of this
interference with metabolism may be explained. If the normal
combustion (i.e. oxidation) of tissue constituents or food materials
is only partial, then acids are usually produced. In conditions
of shock and under chloroform, morphine, or ether in excess,
the alkali reserve is lessened, i.e. the reaction of the blood tends
towards acidity; in the one case, because, owing to the lowered

* See the comprehensive Report No. 7 of the Medical Research Com-
mittee on " Acidosis and Shock." I am indebted to Professor Bayliss
for much valuable help and information conveyed in private letters, the
substance of which appears in the account I have given of shock and
acidosis.

blood-pressure, oxygen is not conveyed to the tissues, and, in the other, because the respiratory centre is rendered less excitable, and so does not respond to the demand for increased lung ventilation necessary to supply more oxygen. We are thus faced with two results of shock : (i) anæmia, arising from lessened circulation of the blood corpuscles, the hæmoglobin of which conveys the oxygen ; and (ii) the decreased supply of oxygen from without due to interference with the normal respiratory compensation. To these factors we have to add others which, at all events in civil practice, make for increased shock. These are the results of severe hæmorrhage, or consecutive upon serious illness or prolonged septic conditions. In cases of so-called delayed chloroform poisoning, we meet with a procession of symptoms resembling in some degree those of shock, as that state is recognised at the present time, even although the patient may have given few signs of pre-existing tendency to the condition. It will be best to reconsider " delayed-chloroform-poisoning " in the sequel.

The anæsthetist has to be prepared to treat shock (i) before the operation by adopting prophylactic measures ; (ii) during the operation ; (iii) in the stage of recovery. Further, he may be required to express an opinion as to the expediency of the performance of an operation under anæsthesia, and to indicate what precautions, *qua* the method of giving an anæsthetic, it may be desirable to adopt.

To assist in arriving at a judgment upon this last point, it must be remembered that the deficiency of the alkali reserve can be detected in the blood of shocked patients, and so can be used as an index of the patient's fitness for operation.

Since the cause of the lessening of alkali reserve (acidosis) is circulatory defect, the introduction of bicarbonate into the circulation must be ineffectual. It is treating a symptom while ignoring the cause, *i.e.* the circulatory depression.

Lowering of the body temperature.—War experience has corroborated the knowledge obtained in civil practice that a severe, even a fatal, fall of body temperature is a concomitant factor of shock. It is unnecessary to inquire in these pages what is the pathogenesis of the lowering of temperature, but we cannot fail to recognise that a depressed blood-pressure and restricted lung ventilation involve diminution of oxygenation in the tissues ; and this result, with diminution of all metabolic

activity, must interfere materially with the heat production, while such nerve control mechanism as exists will equally suffer and be unable to functionate. As will be seen in the sequel, one of the most important factors in successful treatment of shock is the raising and maintenance of the temperature of the patient's body. It is essential to bear in mind that not only is lowered temperature caused by conditions existing before operation, but that these come into action as a result of the " insult to tissue " incident to operation trauma, and so call for treatment, precautionary and other, during the actual surgical procedure. In cases recorded by Cowell, an intramuscular (thigh) temperature as low as 94° F. was met with.

Effects of anæsthetics on shock.—As has been pointed out in various chapters of this book, the clinical symptoms of shock are often evoked as a result of prolonged operations which, however, involve comparatively slight trauma, but the employment of a large quantity of a general anæsthetic. Some of the older methods of anæsthetising lend themselves to excessive dosage, and leave the patient at the close of the administration pale, almost pulseless, with shallow, ineffective breathing, with a greatly lowered temperature and generally profound depression. The return to consciousness from the anæsthetic is marked by prolonged and exhausting sickness, and patients have died during the stage of reaction. The death reputed to be from surgical shock was, it is to be feared, in some measure brought about by the effects of the anæsthetic. Hence we have to recognise two very distinct phases of the action of anæsthetics, the one anæsthesia, the other anæsthetic toxæmia. We know that the symptoms evoked in this last condition are in the main those of acidosis, which is the result, not the cause, of shock. Crile, in his experimental study of shock, claims to have found a definite series of pathological changes in the structures of the central nervous system due, he avers, to inhaling anæsthetics.*

When the condition of the patient at the time of the administration of the anæsthetic is one of depressed vitality—*i.e.* of shock—the effect of the anæsthetic becomes one of supreme importance, and its selection, as well as the method adopted for its exhibition, are so vital as in many cases to determine whether the patient will live or die immediately after the opera-

* *Transactions of Seventeenth International Congress of Medicine in London*, 1913.

tion. Thus Cowell, comparing wound shock and surgical shock, writes : " Just as wound shock may be produced in a few minutes (primary wound shock), so in certain rare instances surgical shock may develop as the result of a sudden nerve stimulus, with or without hæmorrhage, or in an operation probably in association with an unsatisfactory state of anæsthesia." * He adds that the bulk of cases of surgical shock form a common variety of wound shock, marked by continuous fall of pressure towards the end of the operation. During the operation further loss of heat may be produced, among other developments, by the amount and nature of the anæsthetic employed, in its turn producing secondary surgical shock.

The physiological action of the various anæsthetics must be reckoned with when administering them to patients suffering from shock. Chloroform, by lowering blood-pressure, increases one factor of shock. Even ether, although often beneficial in this condition, was found to be dangerous in some types of cases in war surgery ; and Crile's work, which is considered later on, indicates that ether may prove less safe than the mixture of nitrous oxide and oxygen, unless employed by methods safeguarding the patient from its intensive action, and preventing exhaustion which follows prolonged stimulation of the nerve-centres.

It has been said that the amount of the anæsthetic used is important : whether too much in bulk or too concentrated it makes for shock ; further, the chilling effect of many inhalational methods and interference with circulation, as in distension of the bowel in colonic methods, in some cases actually cause shock. Warmed, moist, oxygenated vapours, when inhaled, assist in preserving the body temperature, and so should always be employed.

Upon the other hand, an insufficient degree of narcosis is unquestionably dangerous. It leads to nerve storms and exhaustion, as well as seriously interfering with the surgeon, and so may prolong the operation and necessitate an increase in the surgical trauma.

Although observations made during the war,† as well as experimental research, have to some extent lent support to Crile's conclusions, they have cast a new light upon the question of

* *Op. cit.*
† See Report No. 2, Medical Research Committee, by Major W. B. Cannon, M.D., Harvard, U.S.A.

exhaustion of the cardiac and vasomotor apparatus. We now recognise that in shock the cells of the brain, of the liver and the adrenals, are not themselves shocked in the earlier stages of reaction. Since both pressor and depressor reflexes persist, there cannot be exhaustion of the vasomotor centre. The capacity of this centre for function persists after respiration ceases and the heart is inhibited. The cell changes in the brain which Crile produced in his experiments are probably due to lowered blood-pressure ; indeed, he states that they are less easily produced when measures are adopted to maintain an adequate circulation. Dolley has found similar cell changes produced as sequelæ to shock, and many observers have shown that anæsthesia certainly blocks the passage of afferent impulses to the brain, so that Crile's suggestion of bombardment of the brain by peripheral stimuli occurring during unconsciousness cannot be accepted. It must be remembered that the technique of his experiments is extremely difficult, so that even with the utmost care some experimental errors may easily creep in.

However, ultimately exhaustion of the nervous system may supervene, and when this has occurred, definite changes in the cells of the brain may be found. The heart muscle also, although not defective in the earlier stages of shock, becomes relaxed, and the beats grow less energetic after prolonged depression of the blood-pressure associated with lessening of the alkali reserve. Ether, by over-stimulating the activities of the nerve controls dominating the circulation, brings about such a condition of exhaustion as this, and does so more readily when administered to patients already in a state of shock.

The question of acapnia * in this connexion is important.

* Professor Yandell Henderson ("Fatal Apnœa and the Shock Problem," *Johns Hopkins Hosp. Bull.*, Aug. 1910, 21, No. 233) explains acapnia somewhat as follows : Pain, various emotional states, irregular anæsthetisation, and other conditions such as shock, lead to hyperpnœa. This provokes excessive lung ventilation, causing an excessive escape of carbon dioxide, consequently the blood content of this is greatly diminished. Carbon dioxide being the normal physiological stimulus which keeps the respiratory centre in action, its defect leads to apnœa and respiratory failure, and ultimately to exhaustion. The state produced by lowering the carbon dioxide content of the blood was termed acapnia by Moss. Pain, even in the absence of the carbon dioxide stimulus, will cause the respiratory centre to energise ; but if an anæsthetic or a narcotic such as morphine is given, this abnormal stimulus ceases, and fatal apnœa is evoked. In either case profound exhaustion follows and death ensues,

Professor Yandell Henderson has so far modified his views as to regard acapnia as the result of wound shock or hæmorrhage, and as consecutive to acidosis, so that primary acapnia does not occur. The view now accepted contraindicates re-breathing during anæsthesia, at least in conditions of shock, since, although it may, by increasing the tension of the carbon dioxide, excite respiratory function, it simultaneously lessens the oxygen-supply, and after all it is the oxygen-supply which matters.

HÆMORRHAGE.

Although blood loss is but one of the factors making for shock, it is in very many cases the dominant one, and so demands close attention. To the anæsthetist the results rather than the causes of exsanguination are of moment, so that this aspect of the subject will be considered in the present section.

Young, vigorous subjects under favourable conditions recover rapidly from blood loss, but the older and feebler subjects met with more frequently in civil practice evince less recuperative power. The loss of blood in such cases may arise in the course of pre-existing disease or during an operation. The loss of oxygen-carriers is serious as leading to the general lowered vitality of the organism, a condition which renders it more easily damaged by the anæsthetic even when normal doses are given. Exhaustion following stimulation becomes a dominating peril in such cases.

Hæmorrhage may arise through some pathological state of the patient such as hæmophilia, bleeding from a ruptured ulcer, or a varix in the tissues about the larynx and trachea ; from hæmoptysis or from hæmetemesis. In any of these cases the blood may find its way through the air-passages into the lungs. Hæmorrhage into the pericardium may occur, causing mechanical interference with the heart's action. During operations for the removal of foreign bodies impacted in the œsophagus, great

after the patient has passed into profound shock. Professor Henderson's concept of shock as a failure of the necessary stimulation of the respiratory and vasomotor centres need not be more fully dwelt upon in this place although his experiments and conclusions are full of interest, and in some ways the latter approximate to the views about the causation of shock which have been given above.

trauma not infrequently arises, and laceration extending into the posterior aspect of the trachea is a possible contingency. If the patient is a bleeder, but little can be done to check the hæmorrhage, so that no operation should be undertaken without a thorough investigation of the history of the patient. If hæmophilia is suspected, the endoscope or bronchoscope should replace the knife.

As regards the anæsthetic in these cases, it is obvious that increased blood-pressure and anoxæmic conditions must be avoided. Nitrous oxide, even with oxygen, should not be employed, while ether and ethyl chloride are less safe than chloroform.

Ulceration involving the structures of or between the cardiac end of the stomach, the œsophagus, and the laryngo-tracheal region, may arise in cases of cancer and other diseases, and the occurrence of hæmorrhage will permit the entrance of blood into the lungs. Since in many cases the tendency will be for the fluid to be aspirated towards the lungs rather than to be expelled through the larynx, it is easy to mistake the real cause of the asphyxial symptoms which appear, and to lose valuable time while adopting the routine methods of resuscitation which are appropriate for the treatment of suffocation under an anæsthetic. Whenever fluid has actually entered deeply into the lungs, artificial respiration, when done by Sylvester's method, is dangerous, as it will force the blood deeper and deeper into the lungs until it reaches the bronchioles and air-sacs. On clotting, the blood will render gas exchange impossible and suffocate the patient. The following case exemplifies some of these points * : The patient was a young woman to whom the A.C.E. mixture was administered in preparation for an intrauterine operation. The operation was nearly finished and the anæsthetic withdrawn, when intense cyanosis appeared and the breathing ceased. After artificial respiration was commenced and the sphincter ani dilated, some natural breaths occurred for two

* " An Unusual Cause of Death under [an] Anæsthetic," by Dr. Ernest Playfair, *Lancet*, Dec. 13, 1919, p. 1079. Dr. Playfair has kindly supplemented the published record in a private letter. He says the condition which caused death was not recognised until the autopsy, nor did the symptoms suggest any such serious complication as was found to exist, hence the trachea was not opened, nor any attempt made to clear the air-passages of blood. Indeed, until the patient was inverted there was practically no evidence that blood had entered the lungs.

minutes, although the cyanosis remained unrelieved. The patient was inverted, and a considerable amount of blood escaped from the mouth. The necropsy showed that a varix at the juncture of the stomach and œsophagus had ruptured, and blood had passed into the lungs. Blood was found in the air-passages from the larynx to the bronchioles.

Other remote causes of hæmorrhage directly into the air-ways are : rupture of a blood-vessel in the lungs, and the bursting of an aneurism into a bronchus. It is difficult to indicate any line of treatment likely to prove of any avail in such circumstances, although the anæsthetist must remember the possible occurrence of these complications before undertaking to anæsthetise patients whose condition points to their being liable to such accidents. Further, a knowledge of such possible causes of danger will guide him as to when it is safe to perform manual artificial respiration. The methods of intubating the larynx, withdrawing fluids and introducing oxygen through the tube, or performing a preliminary tracheotomy, are certainly more correct ways of dealing with the danger, although, when fluid is known to have entered the air-passages, inversion is the first step towards resuscitation. Germane to these cases are those in which fluid exists in the pericardium or escapes into it. The case reported by Dr. Gray is quoted on p. 441. Other causes than the rupture of an aneurism into the pericardium may arise and mechanically interfere with the cardiac movements. Here, again, recognition of the true nature of the complication would indicate attempts at removing the mechanical impediment to the action of the heart. Recent advances in the surgery of the heart should offer some hope of success if exploratory measures are adopted.

Hæmorrhage occurring during an operation upon the air-passages.—This is incidental to all operations upon this region, and, as has been pointed out above, the measures adopted to prevent the blood entering the lungs are : maintaining a degree of narcosis in which the cough reflex persists ; the selection of the appropriate posture ; the choice of some method of giving the anæsthetic in which the site of operation can be shut off from the larynx and trachea. Such methods are: performance of a preliminary tracheotomy and plugging the air-passage above the tracheotomy tube ; intrapharyngeal insufflation, and plugging the post-buccal space, as by the use of Crile's tubes (see p. 179) ; and intratracheal insufflation.

With regard to the last-named method, Dr. Shipway * considers it is one of the best. He has used it in 407 operations on the face, mouth, and pharynx for patients between the ages of 12 and 80. In some instances a difficulty may arise in passing the tracheal catheter, this being due to alterations in the anatomical relation of the structures met with, themselves the result of scarring, loss of substance, and so on. In such cases cocainising the pharynx and epiglottis, using a 5 per cent. solution of cocaine, facilitates the proceeding. Further, the position in which the head is placed during the passage of the catheter must be carefully studied, and varied so as to obtain the maximum exposure of the cords. This difficulty is especially liable to occur in war injuries. As regards the use of alkaloids, before the insufflation in these cases, Shipway's experience contra-indicates them for the young, also for patients who are anæmic, asthenic, or are the subjects of toxæmia, also in cases which fall into the epilaryngeal and hypo-pharyngeal groups. Morphine is also undesirable after a tracheotomy has been performed. Except in the cases mentioned above, the preliminary hypodermic injection of gr. $\frac{1}{6}$ morphine and atropine gr. $\frac{1}{100}$ is a valuable aid, as it calms the patient and helps to maintain quietude with a minimal dose of the general anæsthetic. The avoidance of struggling and excitement during the induction is secured by this preliminary medication, and this protects the patient, often an alcoholic, from the strain imposed upon his heart by his struggles. As is indicated in the paper from which I have quoted, the maintenance of the protective reflexes of the larynx is of importance, especially after the return to bed, so that the dose of morphine and the depth of anæsthesia adopted must be determined by this necessity. Septic material is less likely to enter the air-passages with the intratracheal method than in any other, nor, if care be taken, need there be any fear of septic infection arising from the catheter during its introduction. The paramount importance of a strict antiseptic ritual and clear exposure of the laryngeal opening before attempting the intubation must be kept constantly in mind. No complications from septic infection by way of the anæsthetic method occurred in Shipway's cases. Comparing the insuffla-

* " Intratracheal Insufflation of Ether in Operations which involve Bleeding into the Air-passages," *Proceedings of the Royal Soc. of Medicine*, Section of Anæsthetics, 1919, vol. xiii., pp. 1–14.

tion-ether method with the employment of chloroform for operations for the removal of cancerous growths in and about the upper air-passages, Shipway regards the ether method as preferable, but admits the necessity for a full knowledge of its technique and the necessity for the utmost care in carrying it out. Such excellent results certainly call for the possession of wide experience and the most meticulous care.

The results of hæmorrhage, whether occurring before the operation or during it, reveal themselves as shock. How far the patient will be affected will depend upon his antecedent condition and the amount of blood which is lost. The vigorous patients rapidly regain their normal condition, those who have suffered from long-standing disease, especially sepsis, and old and infirm persons, are less tolerant to blood loss. The concentration of the blood becoming increased, and the actual number of oxygen-carriers being diminished by the loss of the blood corpuscles, lead to lessened tissue oxidation. In these circumstances such drugs as morphine and chloroform are harmful ; the former by depressing the respiratory centre, and the latter by lessening the power of the red corpuscles to convey oxygen to the tissues (Buckmaster). The question of postponing the operation until such time has elapsed as is necessary for the patient to recover from the existing shock rests with the surgeon, but from the anæsthetist's point of view delay is beneficial.

The greater the amount of hæmorrhage, the less will be the quantity of anæsthetic required to maintain anæsthesia. In patients exsanguined by repeated bleedings, e.g. cases of severe metrorrhagia, the adoption of the plan of performing the operation in stages undertaken on several occasions is, when possible, safer than carrying out one prolonged operation if it involves much trauma and considerable hæmorrhage.

If the operation must be performed in one stage, instilling saline or rectal irrigation with saline, the semi-inverted posture, and restriction of the anæsthetic within the narrowest limits, the use of warmed vapour and oxygen inhalation, offer the best chances of safety. Provided no valid reason exists contraindicating the use of nitrous oxide and oxygen, that anæsthetic may be used, but anoxæmia is in itself a danger. Though Dr. Crile regards morphine given in massive doses as valuable, yet recent hæmorrhage and inactivity of the respiratory centre are conditions which contraindicate the use of that drug except

in quite small quantities. Oxygen, warmed and run through absolute alcohol, is a valuable aid in cases which are marked by extreme exhaustion.

Anæmia, when extreme, even if not due to antecedent hæmorrhage, calls for similar treatment. Exhaustion of the central nervous system rapidly supervenes upon vigorous stimulation of anæmic patients.

Treatment of shock occurring during anæsthesia.—The attention must be fixed upon what, from our present knowledge, appear to be the dominating factors, the depression of circulation and the diminished oxygen-supply to the tissues.

The first step is to realise that **simple acidosis does not itself cause shock of any kind**, the second is to appreciate the fact that the reduction of the alkali reserve follows the circulatory impairment. The latter involves deficient tissue oxidation. The inadequate tissue oxidation more readily accrues through defective circulation through the capillaries than by reason of a reduction either of the oxygen-carrying power of the blood or of the oxygen tension in the inspired air. In other words, the total bulk of the circulating fluid is of more moment than its qualitative value. It has been shown that " the oxygen tension of the inspired air can be reduced to less than one-half of the normal without seriously impairing tissue oxidation." * Although acidosis may render the reaction of the blood more sensitive to slight increments of carbon dioxide, and so exercises a protective influence, this protection is probably slight. Raising the blood-pressure and increasing respiratory ventilation are soon capable of stabilising the condition at the reduced level of the alkali reserve. It is obvious that this compensatory action must be greatly affected by the condition of the bulbar centres and of the heart and blood vascular mechanism at the time when shock conditions supervene. Lack of sensitiveness of the former such as obtains under morphine and some anæsthetics, and in some pathological states, would seriously jeopardise the patient's chances of compensatory pulmonary ventilation; and diseased or toxæmic states of the blood and a poorly acting circulation would lessen compensatory rise of blood-pressure, while both these departures from the normal would incidentally interfere with an adequate tissue oxidation.

The actual treatment of shock then resolves itself into raising

* Report No. 7, Medical Research Committee, p. 37.

and maintaining the temperature of the body by routine measures such as inhalation of warmed moist air, heat applied by hot blankets, hot-water coils, and the adoption of such a posture as facilitates blood circulation and insures the bulbar centres receiving a proper supply of oxygenated blood. Bandaging the limbs will assist in promoting the end in view. Hot-water bottles, besides their dangerous proclivity to inflict intractable burns, are inefficient. Whenever it is possible to obtain them, electrically-heated mattresses are invaluable. A stove heated by electricity, or even an oil-lamp effectually guarded and draped with blankets, placed under the patient's couch gives far better results. During the operation the vapour of the anæsthetic should be warmed and kept moist. The measures adopted to raise the patient's body temperature should, when possible, be put into operation for some time before the actual operation whenever the patient's state makes such delay possible. But even these precautionary steps will not be sufficient when the volume of blood is insufficient, or when a defect in the quality of the blood prevents the adequate conveyance of oxygen by oxygen-carriers to the tissues, and then it is necessary to take measures to increase the bulk of the blood and to introduce supplementary oxygen-carriers. Of these, the first desideratum is, in most cases, the more important, for as soon as the quantity of the blood is normalised, the conveyance of oxygen to the tissues is automatically secured by compensatory mechanisms in the organism. Introducing saline into the circulation, either by intravenous infusion or by intertissual injection, or even by rectal absorption, has been largely relied upon to restore the normal volume of the circulation. However, even in normal animals introducing large quantities of isotonic saline solution is followed by only a transitory rise of blood-pressure as the fluid rapidly leaves the vessels and water-logs the tissues, rendering them and the viscera œdematous while it flows out into the serous cavities. In shock there is every reason to believe that this effect is more marked since, in that state, the walls of the vessels, as has been pointed out, are unduly permeable. Professor Bayliss has demonstrated that, if a solution of gum arabic * filtered and sterilised and of a strength of 6 per cent. in 0·9 per

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* Bazett prefers the weaker mixture, and gives the formula : " Gum acacia, 50 grammes, sodium chloride, 9 grammes, tap-water, 1 litre. This is dissolved, filtered, and auto-claved."

cent. of sodium chloride solution is employed intravenously, the blood-pressure is rapidly raised and maintained at the normal height, provided that the pre-existing heart condition is such as to render circulation possible. In this way capillary stasis is prevented and oxidation of the tissues becomes possible, even although there exists some deficiency of hæmoglobin. The addition of sodium bicarbonate, recommended by the Committee in their Fourth Report, is, in the light of later experiments, to be deprecated since, as I have attempted to indicate, the aim in view is not to increase the alkali reserve, but to restore the normal volume of the fluid in circulation. It must, in this connexion, be remembered that excess of alkali interferes with the respiratory centre, and so is dangerous.

Experience seems to show that the treatment of persons suffering from a severe hæmorrhage, when undertaken before the anæsthetic is given, may be successfully pursued by administering saline solution by the mouth and bowel rather than by injecting it into veins or tissues.

It is pointed out in the Report on Acidosis (No. 7) that, if in cases of marked acidosis certain symptoms arise—such as air-hunger—which indicate an undesirable rise in the H-ion concentration of the blood, sodium carbonate may be given separately from the gum saline solution by the mouth or rectum, or a cautious intravenous injection of the isotonic 2 per cent. solution may be made.

Failing with such measures, resort to transfusion of blood becomes necessary.* Two methods are available. In the one case direct transfusion of the blood from a healthy donor to the patient, and in the other (indirect), by the use of Vincent's tubes containing the donor's blood. These tubes can be sterilised and prepared beforehand and kept ready for use.

The Direct Method.—In Colonel Fullerton's method the artery of the donor is joined with the vein of the recipient by a short length of thin-walled tubing connected by silver cannulæ. The apparatus is lined beforehand with a thin coating of paraffin and kept sterilised for use. The donor's wrist, since the radial artery is selected, is placed close beside the recipient's

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* For full particulars of these methods, see the Report (No. 4) by Captain O. H. Robertson, M.O.R.C., U.S.A., *passim*, and Captain Bazett's valuable article on " Shock " in *The Manual of War Surgery* (Barling & Morrison), p. 407.

elbow.   The artery and vein are dissected out under local anal-
gesia and tied distally.   Artery clamps are applied on both the
artery and the vein.   The artery cannula is placed in position
and the tubes filled with blood, and then the cannula is introduced
into the vein.   Direct transfusion has drawbacks such as its
greater liability to sepsis.   Bazett estimates 800 c.c. of blood
to be the dose to be aimed at.   The condition of the donor
needs careful watching.   If the donor and the recipient are
not known to belong to the same group, the blood transfused
may be incompatible.   This is shown by the recipient complain-
ing of pain chiefly in the back, of great distress and severe
nausea.   Should such symptoms arise, the transfusion must
be stopped at once.

Indirect transfusion.—The Vincent's tubes are cleansed with
water, chloroform, alcohol, and ether and placed in a clean towel
and sterilised in an auto-clave.   After being paraffined, the
tube is ready for use.   The largest vein at the bend of the elbow
is selected and a cannula introduced peripherally.   The vein
can be kept distended by using the Riva-Rocci armlet.   The
apparatus, when filled, is connected with the vein of the re-
cipient by introducing the cannula into the central end of the
vein, and the blood forced into the vein by an air-pump attached
to the air tube.   When nearly empty, the cannula is withdrawn
to avoid air embolism.   It is wise to have several tubes ready,
so that when one is nearly emptied it can be replaced at once
by a full tube.

If preserved blood cells are employed, an anti-coagulant is
necessary, and the consensus of experience appears to be in favour
of the use of citrated blood.   The methods of preparing and of
use of such blood are simple, but require great attention to
detail, as well as the employment of a special apparatus.   The
methods are fully set forth by Captain Robertson's Report.*

Reaction and choice of suitable donors.—Some bloods, when
mixed with others, cause agglutination and even hæmolysis,
so it is advisable to test the blood of the patient and that of the
donor before transfusing.   W. L. Moss † has shown all persons
can be divided into four groups as regards agglutination and
hæmolysis as is set forth in the table given below. Since hæmolysis

* Report No. 4, Medical Research Committee, pp. 10 *et seq.*
† *Johns Hopkins Hosp. Bull.*, 1911, 22, 238.   This subject is fully dis-
cussed in Report No. 4 of the Medical Research Committee.   .

follows agglutination, it is not necessary to consider it. Although it is best to select a donor belonging to the same group as the recipient, this is not a *sine qua non*, the one important matter is

Serum of Group.	Cells of Group.				No. of Persons in Group.
	I.	II.	III.	IV.	
I. . . .	o	o	o	o	I. = 8 per cent.
II.. . .	+	o	+	o	II. = 40 per cent.
III. . .	+	+	o	o	III. = 12 per cent.
IV. . .	+	+	+	o	IV. = 42 per cent.

+ = agglutination.   o = no agglutination.

that the bloods of the donor and the patient shall not agglutinate when mixed. Group IV. contains persons whose blood does not ever agglutinate when added to the other groups, and so is of general utility.

. **Testing the blood for agglutination.***—A few drops of the donor's blood obtained with aseptic precautions are taken and added to one drachm of a 1.5 per cent. solution of sodium citrate.

Small drops of sera of Groups II. and III. are placed on a glass slide, and a small drop of the donor's citrated blood is added. Agglutination, if present, is detected at once. Agglutination in both indicates Group I.; in serum III. = Group II.; in serum II. = Group III. Group IV. are not agglutinated by either serum. When stock sera are not available, the blood of the donor is tested similarly against the recipient's serum. If agglutination occurs another donor is tested.

When there is no time for such testing it may be omitted. If signs of incompatibility of the bloods of the donor and recipient appear, the transfusion must in this case be stopped. The donor's blood is usually so rapidly diluted by the blood of the recipient that the danger soon passes.

To sum up the lines of treatment of shock under anæsthesia, it may be said that the essentials are : (i) raising the patient's body temperature and maintaining it ; (ii) adjusting the patient's position so that the circulation of blood is carried on with the greatest facility and the central nervous system receives a full supply of oxygenated blood ; (iii) that this *position be rigidly*

* See *Brit. Med. Journ.*, Nov. 24, 1917, quoted by Bazett, *op. cit.*

maintained throughout the operation and for some hours after the patient has been returned to his bed; (iv) that the anæsthetic used be carefully selected, and the method of its use chosen with a view of avoiding the addition of anæsthesia shock to the trauma shock; (v) that the anæsthetic vapour be warmed and moistened and given in sufficiently limited quantity; (vi) that warmed oxygen gas be ready for immediate use, and freely employed when required.

GENERAL MORBID CONDITIONS.

The condition called the **status lymphaticus** or **lymphatism** has for some years received great attention. It is a commonly accepted theory that very many deaths which occur under anæsthetics are due to this disease, and, indeed, are of the nature of unpreventable accidents which, although associated with anæsthetics, are only indirectly the result of the use of such drugs. The subjects of the status lymphaticus are liable to sudden death as a result of some wholly trivial circumstance. Thus, stepping into a cold bath, even receiving a prick with a hypodermic syringe, has caused death in lymphatism. The long list of such fatalities under anæsthetics administered to persons suffering from lymphatism favours the belief that these patients incur a more serious risk than falls to the lot of other persons who inhale anæsthetics so frequently and without scathe. As a rule these patients die before or in adolescence, and so deaths under anæsthetics among them are most common in childhood. They appear intolerant of depression of blood-pressure, and of even moderate overdosage of an anæsthetic, two facts which should be borne in mind in anæsthetising them. However, unfortunately it is seldom possible to diagnose the condition during life.

I have discussed this question fully elsewhere.* The main phenomena of lymphatism are: general hyperplasia of the lymphoid structures of the body—*e.g.* the follicles of the tongue; the glands of the neck, axillæ, groins, and abdomen are enlarged; post-nasal adenoid vegetations and enlarged tonsils are present; a persistent thymus is common, while in 50 per cent. of the cases the thyroid gland is enlarged. The patient is commonly irritable, inclined to be fat, is easily fatigued, pasty of look

* " Status Lymphaticus," a clinical lecture, *Lancet*, Aug. 6, 1910.

and suffers from cold extremities. The heart is often small,
as is the aorta, and the circulation sluggish. Thymic asthma
may exist, but not commonly. There is, however, great difficulty
during life in deciding whether any given individual suffers
from this condition. As a rule, no unusual symptoms reveal
themselves during the induction of the anæsthesia, but these
patients appear to have little resistance to the anæsthetic, so
that the quantity and the vapour strength employed, even
if well within the usual zone of safety, may in the case of those
suffering from lymphatism lead to fatal results. It is, however,
probable that these individuals do not run greater risks during
anæsthesia than do others whose vitality is depressed and whose
circulation is feeble. The state is allied to cretinism and in-
fantilism.

Graves' disease : Exophthalmic goitre.—As in the case of
status lymphaticus, those who suffer from these conditions are
peculiarly liable to sudden death under an anæsthetic. Without
entering unnecessarily into the regions of theory, it may be
pointed out that, associated with the anatomical impediment
to respiration commonly present, these patients are in a state
of toxæmia which renders their circulation peculiarly unstable
and their nervous system especially subject to psychic shock.
Chloroform has been associated with many of the deaths ; but
as the fatalities have often occurred without overdosage or
that irregular intermittent system of exhibiting the drug which
Levy regards as so dangerous, it cannot be said that chloroform,
if given dosimetrically, is an inappropriate anæsthetic.

If ether is employed, as it frequently is, and by an open method,
there is a risk of excessive secretion suffocating the patient,
as well as of over-stimulation leading to exhaustion and collapse.
It is in these cases that the preliminary employment of morphine,
scopolamine and atropine is peculiarly valuable. It must again
be pointed out that these persons do not easily tolerate even
usual dosage of the general anæsthetic. Crile's method of dealing
with these cases is referred to above (p. 366). I am convinced
that reliance upon local analgesia alone is courting danger, as
the psychic shock is the chief peril against which these patients
have to contend.

Angio-neurotic œdema is a condition in which the patient
is liable to a sudden and inexplicable development of œdema
at various situations. So far as anæsthesia is concerned, the

danger point is the respiratory tract, and to avoid suffocation occurring when no surgical aid is rapidly available, a precautionary tracheotomy may be required. Further, œdema of the larynx may arise in the course of an ordinary operation in the case of a patient whose liability to this complication may not have been known before the anæsthetic was undertaken. I have met with two cases, one in which the disease was known to exist, and another in which œdema developed only under the anæsthetic. My experience convinces me that both nitrous oxide and ether should be avoided and chloroform given. If œdema develops, tracheotomy must be performed at once.

Acute œdema in renal disease.—A similar danger may arise in the case of persons suffering from kidney disease. Its possibility must be borne in mind whenever albuminuria is present, and precautionary measures adopted. The symptoms and treatment are similar to those mentioned above.

PROPHYLAXIS.

Measures to this end involve a **correct choice** of the anæsthetic, the proper **preparation** of the patient, and the adoption of the appropriate **posture** during the operation.

Dangers may arise from the selection of an unsuitable anæsthetic : e.g. (a) nitrous oxide gas for a patient with obstructed breathing due to inflammatory swelling, œdema of the larynx, of the pharyngeal structures, or of the deep tissues of the neck ; (b) ether for a patient whose bronchial tubes and pulmonary alveoli are choked with secretion ; (c) chloroform for a patient whose heart is beating feebly and blood-pressure is markedly low, as in the case of persons suffering from recent severe shock. The selection of the anæsthetic is gone into fully in Chapter II., pp. 28–56.

Faulty preparation of the patient * may and frequently does lead up to serious but preventable complications. When directions are given about the diet, clothing, and regulation of the patient's bowels, too little attention is often paid to the effects likely to result from the anæsthetic itself. Weakly subjects, and especially children, are frequently left too long without nutriment, or are allowed to take indigestible food. Beef-tea, for example, is sometimes ordered to be given at unsuitable

* This subject is discussed fully in Chapter II., p. 22.

times—*e.g.* 5 a.m. or 6 a.m. It is very much better to diet the patient with care for one or two days before the anæsthetic is given, and in serious cases this should always be done. Alcohol given before the anæsthetic is inhaled is always harmful. It is, in my experience, better to rely upon the stimulant action of hot water taken three hours before the operation ; it may be flavoured with tea. Rectal feeding is far better for weakly subjects than food taken by the mouth. It can be employed to within an hour or so of the operation. Glucose in warm saline (ʒi. in ℥vi.) is the best form of rectal feeding, and may be given every four hours.

Weakly patients should not have strong aperients administered on the night before the operation. It is better that such purging as may be required should be done a day or so previous to that on which the anæsthetic is to be inhaled. Even an enema used just before the operation in some patients may produce prostration. An equally important matter is the maintenance at the normal height of the patient's temperature, as this lessens shock. Loosely fitting warm clothing should be arranged to cover the chest, abdomen, and limbs. The room in which the operation is performed should be kept at 65° F., or even 70° F. ; but thorough ventilation is essential. It is equally necessary to warm the room into which the patient is carried after the completion of the operation. Many cases of collapse attributed to ether bronchitis are really due to the neglect of this precaution. Arrangements for warming the operating table should be made, but every precaution against burning or scorching the skin is imperative.

To **anæsthetise a patient in bed,** and then to carry him into another room for the operation, is certainly a dangerous proceeding. If circumstances exist which render this unavoidable, there must be no rough and unskilful lifting. The " head lower than the body " posture **must** be preserved in carrying : jolting and jerking **must** be avoided.

The utmost attention should be paid to the posture of the patient when on the operating table. It is easy to observe or ascertain in what position in bed he lies when breathing with the greatest ease, and this position should be adopted for the patient as far as the requirements of the surgeon permit when the patient is placed upon the operating table. This is especially important in the case of patients suffering from goitre, heart

disease, aneurism, empyema, obesity, large abdominal tumours, and in those who are very old or very feeble.

POSTURE OF THE PATIENT UNDER AN ANÆSTHETIC.

The usual positions in which a patient can be placed during operations under anæsthesia are as follows :—

The Dorsal Decubitus, when the face looks straight upwards and the limbs are lying straight. The arms are usually in the way, and are liable to fall off the table or get pressed against its edge, so that musculo-spiral paralysis may ensue. To prevent this arm and wrist bracelets and rings must be removed, except the marriage ring which, if heavy, may be covered with gauze. The hands are then placed palm downwards, the fingers and thumb spread out and put under the buttock of the corresponding side. This can only be properly done by rolling the patient first to one side and then to the other. The arms are drawn down and pushed close into the sides. If the table is very narrow and the arms cannot be securely fixed by the waterproof sheet, a bandage from wrist to wrist may be placed *behind* the patient's back. Patients often suffer severe backache after a prolonged operation in this posture, so that a small pillow, folded towel or blanket may be placed under the "small of the back," and this prevents the symptom. Unless the patient has a short, thick neck, or cannot have his head lateralised with comfort, it is best to turn the head so that he looks to the right hand or the left according to the side on which the operation is to be performed. In most cases, the head and shoulders should be raised to the height which suits the patient's comfort. When anæsthesia is produced, the head should be lowered. For operations in the region of the upper abdomen, increased relaxation can be obtained by raising the head and shoulders and flexing up the thighs. Infiltrating the recti muscles with very dilute novocain (1 in 200) solution assists in overcoming the rigidity. Raising the arms and fixing them above the head or on the chest is dangerous ; it is liable to produce peripheral palsy and always impedes breathing.

The lateral posture.—The patient is turned with his head on the side, the shoulders and the pelvis tilted to a right angle to the plane of the table. The lower arm is drawn through

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from the back so that the weight of the body bears upon
the subjacent shoulder. A small pillow under the thorax helps
to prevent undue pressure upon the arm. The upper arm is
either supported on an arm-rest such as that devised by Mr.
Carter Braine (see fig. 79, p. 357), or is held off the chest by
an assistant. The lower thigh and leg are flexed so that the
body does not tend to fall over. A pillow or sandbag placed
against the patient's back will assist in maintaining him in
the desired position. The colour of the lower arm and hand
should be noted from time to time, and if it becomes mottled,
it must be relieved from pressure. This complication is usually
due to the patient's tendency to fall on to his face. The position
is usually adopted in renal and some gynæcological operations.
It is not a safe one for operations upon the thorax. In that
case the patient is placed midway between the dorsal and the
lateral position and kept in place by pillows or sandbags.

Gynæcological positions.—In the usual position the patient
lies upon her side and both knees are equally drawn up;
in Sim's position both knees are drawn up, the right one above
the left and both touching the couch, the left arm is placed
behind the back. These positions give little difficulty to the
anæsthetist, although in stout patients the breathing is at times
somewhat less easy. If the pillow is drawn well through so
that the patient's face rests upon its edge, the mask used for
the anæsthetic can be easily applied.

Position of patient in spinal anæsthesia. — The posture
(Barker) for injection is a modified lateral one. The head and
shoulders are considerably raised so that the summit of the
spinal column is the highest point of the spinal canal. The
head is flexed fully. The trunk is so arranged that the
vertebræ form a prominent bow with its convexity towards
the person who will make the injection. The upper segment
of the trunk is made to lean over in the same direction. The
thighs are flexed strongly on the pelvis, the legs upon the thighs.
These arrangements are made with the object of accentuating
the bow made by the vertebral column and bringing the spinal
processes into prominence. When the injection has been made,
the patient is rolled into the dorsal decubitus, but the head and
shoulders are kept at a higher level than the trunk until such
time has elapsed as is judged sufficient to ensure fixation of
the analgesic employed. For details see pp. 503-4.

The alternative posture is one in which the patient sits on the side of the table, his feet resting upon a chair. The head and shoulders are bent down so that the vertebral column is bowed backward towards the person who is to make the injection. Subsequently the patient assumes the dorsal decubitus, his head and shoulders being kept raised to the required height above that of the trunk.

The semi-prone posture.—This is the lateral position modified by turning the patient so that his body leans well over towards the table. A pillow is placed between the bony thorax and the table, the head being arranged upon a pillow so that the face is kept free from interference by the pillow and cloths used to cover the trunk and shoulders. Care must be taken that whatever position the shoulders and pelvis are placed in is not liable to be changed without the knowledge of the anæsthetist. The respiration is more or less hampered in this posture. The use of the arm-rest greatly assists respiration.

The prone posture. — The patient lies upon his thorax and abdomen, the shoulders and pelvis are on planes parallel to the table. A pillow is placed beneath the thorax so as to allow of some respiratory excursion. As a rule it is possible to have one shoulder lifted off the table, and this facilitates breathing. This position is at all times one which embarrasses respiration and calls for close watching to avoid danger. For operations on the cerebellum, for resection of the cervical nerves for torticollis, the prone position is usually required. The safest way in these cases is to use a special head-rest which, while fixing the seat of operation, takes pressure off the thorax and so prevents to some extent respiratory embarrassment. Cushing has devised an excellent arrangement for this purpose. A metal apparatus is fixed to the table so that both shoulders are lifted three or four inches off the table. A cup-shaped head-piece supported by a vertical stand takes the patient's face. There is a gap in this cup to admit the mouth and nose, so that a mask for administering an anæsthetic can be applied. In this way there is but little interference with breathing and the anæsthetist can readily get at the face to give the selected anæsthetic.

The lithotomy position has been already mentioned. It is the dorsal posture with the head turned to the right, while the thighs are flexed strongly on the pelvis, the legs on the thighs. This is preferably done by uprights fixed to the table, the thighs

being abducted and rotated outward and the feet secured by bandages to the ankle-pieces attached to the uprights. Unless complete, even deep, narcosis is secured before the first incisions are made, there is a tendency for a reflex extension to take place —the thighs on the pelvis and the legs on the thighs, so that it is always wise to have the limbs held in position by an assistant until this moment of stress has passed. If a Clover's crutch is in use, the strap should be passed *over* the left and *under* the right shoulder, otherwise undesirable pressure may be made on the neck. Excessive flexion of the thighs on the abdomen in fat patients may cause interference with breathing, while the rings which secure the legs may exert undue pressure upon the popliteal space and damage the vessels in extreme flexion.

The Trendelenburg position.—The patient is anæsthetised in the dorsal posture, and then the table is tilted so that the head is almost vertically below the pelvis. The degree of tilting will vary with the exigencies of the operation. To prevent the patient sliding down, the lower flaps of the table are let down, and the legs, which should have been secured to them by bandaging, are flexed to a right angle. The popliteal space and the lower end of the thighs must be well padded to avoid injury from pressure. The best tables have blocks which support the shoulders and prevent their sliding down. The arms are arranged as in the dorsal decubitus. Extreme inversion has several drawbacks. Respiration is hampered by the pressure of the abdominal viscera upon the diaphragm, which interferes with its rise and fall. In some patients cyanosis occurs in this position, and oxygen is needed to prevent undue venosity of the blood. The right heart is certainly severely taxed in some cases, and the pulmonary circulation interfered with. Œdema of the face, seen especially in the loose tissue about the eyes, may appear. I have met with cases in which the patient's condition became so unsatisfactory that the extreme degree of inversion had to be given up. McCardie states that post-operation lung trouble, pneumonia and embolism (Zweifel) are liable to occur after the use of this posture. Intestinal obstruction, acute dilatation of the stomach, decrease in the urinary secretion, surgical emphysema, and apoplexy have been recorded as sequelæ of the Trendelenburg position. Schnitzlet and Moynihan state that prompt change of the patient's position to the prone decubitus with straightening of the legs will

give relief and save the life of the patient if adopted as soon as the acute dilatation of the stomach is observed.

Dorsal decubitus with extension of the head.—Some surgeons require this position for operations on the palate or post-nasal space.   The patient lies on his back, a sandbag is placed behind the shoulders and the head extended strongly.   More extreme extension is at times obtained by allowing the neck to rest upon the end of the table while the head hangs down.   This posture is undesirable and usually unnecessary.

The sitting posture.—The patient is placed in a chair, his head is slightly extended and is supported by a head-rest such as is attached to a dental chair.   A strap is used in some cases to prevent the arms being raised or the patient sliding out of the chair.   This is, however, unnecessary and undesirable, as by tilting the back of the chair slightly backwards, the weight of the trunk prevents sliding forwards.   The arms should not hang down, but should be placed in the patient's lap, the fingers of the two hands being intertwined.   The feet should hang freely if gas is given, otherwise, if any muscular rigidity develops, the patient will be pushed up out of position.   Over-flexion or extension of the head must be avoided or breathing will be interfered with ; further, all wrappings of the neck must be removed.   The question of the safety of this position for operations upon the upper air-passages has led to much discussion. It is certainly a dangerous one for patients who are in poor health, in cases of feeble circulation and embarrassed breathing, so its adoption should be preceded by careful examination of the patient.   Although some authorities regard this posture as safe even when chloroform is employed, I think that it certainly increases the risk of circulatory collapse.   The semi-sitting, *i.e.* the reclining, position is safer; but even when this is adopted, the patient should be anæsthetised with gas and ether and in the dorsal pose, and subsequently his shoulders and head can be raised to the required extent.

The semi-sitting (reclining) posture. — The patient, placed in the dorsal decubitus during the induction of anæsthesia, is subsequently raised so that the trunk is flexed upon the pelvis, while the head is **slightly** extended.   This position is the best one in which to place a patient after his return to bed, but in this case the head should be placed in the vertical axis of the body.   In some rhinological procedures this posture is varied,

the head being flexed upon the trunk and steadied in position by a stiff pillow placed behind the shoulders and head.

The posture best for operations for empyema thoracis.—If there is no communication between the empyema and a bronchus, the chief danger is caused by pressure upon and interference with the heart's action and the movements of the sound lung when the patient is made to lie upon that side. The dorsal position should be adopted and the patient should, in the case of a left-sided empyema, be turned as little as possible towards the sound side. When, however, the empyema discharges by a bronchus, if the affected side is raised to a higher plane than that of the sound side, a great risk is involved of draining the pus into the unaffected lung, thus causing suffocation. The accident, which is usually fatal, may occur with even a very slight degree of rotation of the trunk. These rules apply chiefly to operations performed under a general anæsthetic, but the accident indicated, since it is mainly mechanical, may occur during local or regional analgesia.

Emergency requisites.—Preparations should be made for all possible contingencies. Sterilised tracheotomy instruments should be ready at hand. Cylinders of oxygen must be in the room. Tongue forceps, gags, transfusion and infusing apparatus, and warm normal saline or Locke's fluid * may all be needed in cases when severe operations are contemplated, or the condition of the patient is critical.

General precautions.—It is often wise, especially in the case of mouth breathers, to place a dental prop between the teeth before administering the anæsthetic. The prop should, as a matter of course, be secured by fishing-line to a counter-weight such as a pair of pressor forceps. Fixing tongue forceps on the tongue as a routine measure is unnecessary, and causes pain after recovery from the anæsthetic. When securing the tongue is considered advisable as in operations on the nose, tongue and jaw, the least painful plan is to pass a thread transversely through the anterior part of the dorsum of the tongue, knot the thread, and attach pressor forceps to the two free ends.

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* The advantages of Bayliss's gum saline solution and blood solutions are discussed above when considering shock, and it is shown that the gum saline is more efficacious than simply normal saline. It is essential that the gum should be completely dissolved, as, if any particles remain, they may act as emboli and cause infarction.

Silence and avoidance of all noise during the induction of anæsthesia must be insisted upon.

The attention of the anæsthetist should be concentrated on his work and on his patient. However desirous he may be to " lend a hand " as an assistant to the operator, he should resist the temptation and restrict his energies to his peculiar province. He has quite enough to do, and while handling his apparatus he cannot be surgically clean. It is important to see that the apparatus for anæsthesia is properly cleansed before use, and that the agents used are fresh and in their respective bottles and places. If the patient is lifted or moved, the anæsthetist should withdraw the inhaler during the change of posture, and should redouble his vigilance, as many dangers may arise at such a moment—*e.g.* syncope, vomiting.

In this place, I may again caution against giving chloroform in a small room in which illuminating gas or a lamp is burning. The decomposition of the anæsthetic, arising from the burning of its vapour, will be a sure source of danger to the patient and those engaged in the operation.

The use of the actual cautery.—Patients may inhale ether or ethyl chloride before the use of the cautery in their air-passages. If a breath or two of air is allowed before the cautery is applied, there is no danger of the expired air exploding. Dr. Inglis Clark was kind enough to make some careful experiments with ethyl chloride for me in this connexion, and his results accord with my clinical experience.

MINOR COMPLICATIONS.

Such troublesome complications as breath-holding, panic, belching, hiccough, pharyngeal cough, and sneezing have been dealt with in preceding chapters. One complication may be mentioned here, viz. maniacal excitement during the induction of anæsthesia. As a rule, unless the patient's antecedent history, his habits, and his temperament point to the likelihood of these maniacal seizures, danger is absent. I have met with cases, however, of persons usually calm and under self-control, who during recovery from ether anæsthesia have become greatly excited and violent, so that no patients should be left unwatched until they are fully conscious, and have recovered self-control. I know of a case in which a dentist had his operating-room

wrecked by a patient, a military man, while coming round from nitrous oxide; in another case, an anæsthetist of small physique incautiously permitted his patient to get hold of the Clover's inhaler. This he promptly threw through the window. Alcoholics, unless rapidly anæsthetised, become violent, and they are liable to great excitement during the stage of recovery.

I. Accidents connected with Respiration.

Anatomical conditions such as cicatrices dragging down the skin, and so fixing the larynx,* goitres, and intralaryngeal growths, may cause dyspnœa and alarming interference with respiration, as soon as the patient is partly under an anæsthetic. Faulty position of the patient's head may lead to similar accidents. The dropping of the chin upon the breast and the over-extension of the head while the jaw is permitted to fall are examples of faulty posture. Dyspnœa arises when, through spinal disease, the thoracic muscles are paralysed and the respiration is entirely diaphragmatic. As a rule, the difficulty in respiration becomes much exaggerated during narcosis. Obese persons also, when placed in the head down position, breathe badly.

Foreign bodies may become loose in the mouth, and either get drawn into the larynx and thence into the trachea, or may become impacted, and so set up laryngeal spasm.† Small plates carrying artificial teeth are especially dangerous, and obturators, pivoted or loose teeth, may also become sources of peril. During an operation teeth, or pieces chipped off teeth, or masses of tartar, may fall back ; and even portions of epitheliomatous or other growth, blood-clot, pus from the bursting of post-pharyngeal abscesses, blood from epistaxis, detached tonsils and turbinate bodies which have slipped from the guillotine or turbinotome, nasal polypi, vomited undigested solid

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* I have met with several such cases. They are especially troublesome when the mouth and chin are dragged down to the chest, and when the tongue is fixed to the floor of the mouth. Dr. Leonard Guthrie narrates some typical instances in his thoughtful brochure, " Chloroform-Narcosis in Children," p. 53.

† A round worm vomited from the stomach has under an anæsthetic passed into a bronchus and caused asphyxia.

food, plugs of chewing tobacco, gags, portions of snapped-off forceps, and bits of sponge may obstruct breathing. Profuse salivation associated with increased secretion from the bronchi causes respiratory difficulty, and the patient becomes suffocated by his own secretion, unless the gravity of the situation is realised and prompt measures are adopted to remove the danger (a case of this nature is cited above, p. 213). When the tongue is partially removed, the stump is liable to fall back and cover the glottis ; and similarly, after removal of a portion of the lower jaw, the whole tongue is often carried back by its own weight. This may also occur in deep narcosis, even when the jaw is intact. Such an accident has happened more than once after the infusion of hedonal. The fingers inserted in the mouth during tooth extraction often push the tongue back, and complete occlusion of the air-way results unless this is noticed and remedied.

Precautions.—All loose bodies should be removed from the mouth before operation. The anæsthetist should ascertain if the patient has taken any solid food on the day of operation. It is a good rule in dental surgery never to operate upon the second tooth, when extracting several teeth, until the first tooth extracted is known to be *out of the mouth* ; and care should be taken that the forceps are freed from the tooth just removed before they are employed again. A Carter's oral spoon (see fig. 11, p. 74) held in the mouth during tooth extraction prevents teeth falling back and from being drawn into the larynx. In prolonged operations, when possible the head should be placed on its side, to obviate the weight of the tongue carrying it back ; this will also facilitate the expulsion of blood.

Treatment.—In the event of any foreign body becoming loose, the jaws must be separated by a mouth-opener, a gag inserted, and the substance sought for with the finger. The patient's head and shoulders should be lowered, and efforts should be made to excite the laryngeal reflex by drawing forward the epiglottis by means of a bent tongue depressor, or forceps. Slapping the back certainly aids. When bronchial secretion is profuse, and when blood, pus, etc., have been aspirated into the trachea, the patient's head is to be turned to the side, and, if a dental prop is not already in position, the mouth must be opened and the pharynx mopped out. When these measures are obviously ineffectual, the patient must be inverted and the

secretions allowed to drain out, their passage being assisted by pressure upon the chest. Schäfer's method of artificial respiration is applicable to all such cases (see p. 434).

In the case of a **solid body** entering the air-passages, unless it can be seen and removed by means of forceps, the air-way must be opened, and if possible, the occluding substance removed. In some cases the dyspnœa, which at first threatened life, passes off, probably owing to the position of the foreign body becoming altered. When this happens, it is better to delay surgical proceedings and subsequently perform a formal operation at a suitable time ; but, as Sir Rickman Godlee points out, " the inconvenience of an early tracheotomy and the resort to the usual methods of search are not for a moment to be weighed against the possibly irremediable damage that may be done by even a few weeks' residence of a foreign body in a bronchus." *

When teeth, fragments of teeth or of metal stoppings, enter the air-passages, cough of a distressing character is set up. This may increase, and if the cause of obstruction is not expelled the dyspnœa calls for immediate relief by tracheotomy and inversion, or the immediate urgency may pass off. Later on the foreign body may be coughed up, although sometimes it may give rise to an abscess, and be subsequently expectorated ; in other cases local septic pneumonia of painful chronicity is developed. Recorded cases have terminated fatally after prolonged illnesses, so that no pains should be spared to avoid this grave complication.

The introduction of the bronchoscope now enables the surgeon to ascertain the precise position of any solid body and to remove it. This is the best method of dealing with such cases after the immediate and urgent dyspnœa has passed off.

Vomited matters. — When, through the exigencies of the case or inadvertence, food has been taken within a few hours of the administration of an anæsthetic, vomiting is likely to occur, either when the operation is proceeding or as the patient is regaining consciousness. There is great danger lest vomited matters be drawn back into the larynx, leading to asphyxia. †

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* *Trans. Med. Chir. Soc.*, vol. lxxix., p. 206.

† The following case illustrates this danger : A hospital patient requiring a minor operation was instructed to abstain from food and present himself in the evening for the house surgeon to operate. The operation was performed—the patient being skilfully anæsthetised by a resident house

When it is necessary to operate upon a patient who has recently taken food, it is certainly wise to wash out the stomach either before the inhalation or as soon as the patient is sufficiently insensitive to permit the lavage without struggling.

Respiration may also be **hampered** by—the **posture** * of the patient ; by pressure upon his chest due to assistants leaning upon him ; or by tight bandaging ; also in edentulous persons, especially if nasal stenosis exists, the lips may be sucked in during inspiration, causing some cyanosis and inspiratory dyspnœa. This complication frequently arises before the patient is fully under the anæsthetic, and prevents his passing completely into the third degree of narcosis. It is at once relieved by inserting a gag, which keeps the lips apart and allows the anæsthetic to be inhaled. Mechanical interference with breathing may occur in feeble or stout or emphysematous persons, if they are placed on the side, or in ricketty children. The same difficulty may be experienced in using the lithotomy or Trendelenburg position. Fluid in the chest also causes dyspnœa. Gradually failing respiration, leading ultimately to cessation of breathing and associated with deepening duskiness, may arise from too little air being given or from a slightly excessive percentage of anæsthetic. It is not uncommon when such mixtures as the A.C.E. or C.E. are used. To relieve the condition, the inhaler must be withdrawn, the mouth opened, and rhythmic traction made on the tongue (Laborde's method) ; this should be supplemented by one or more vigorous compressions of the chest. In applying Laborde's method, the lower teeth should be covered with some layers of gauze to prevent their tearing the under-surface of the tongue. The tongue is drawn well out of the mouth while the inspiratory stage of artificial respiration is in process ; during the expiration the tongue is allowed to retract. These measures as a rule suffice for minor degrees of respiratory difficulties under anæsthetics.

physician ; but during recovery he vomited, and large masses of undigested meat were taken from the mouth. Asphyxia being imminent, laryngotomy was performed, but the patient died, and the necropsy showed that a mass of meat had entered the trachea, and lay at its bifurcation, occluding the bronchi. It transpired that the man had, in spite of explicit directions to the contrary, partaken of a heavy meat dinner just before coming to the hospital.

* The bearing of posture upon the safety of a patient under anæsthesia is discussed on p. 417.

In cases of **intestinal obstruction** the **regurgitation** of the contents of the stomach and intestines into the mouth, and their subsequent aspiration into the air-passages, may occur.* Although this condition was dealt with above in speaking of the best methods of giving the anæsthetic in these cases (see p. 378), it may be well to recur to it here. The welling of fluid from the alimentary canal is not a true vomiting, but is rather of the nature of reversed peristalsis. As soon as the anæsthetic takes effect and lessens the tonicity of the cardiac and pyloric sphincters, the intra-abdominal pressure becomes relieved by unloading the intestinal contents upward along the line of least resistance, instead of along its normal route. When this regurgitation occurs, every effort should be made, by turning the head to the side, to divert the regurgitated fluid away from the air-passages. Lavage, when practicable, should be performed before the anæsthetic is given, and frequently repeated. The insertion of a gag between the teeth before giving the anæsthetic is an additional precaution which is useful. Constant swabbing out of the mouth, and syphoning the stomach contents by a rubber tube discharging into a pail, help to keep the air-passages clear. As has been pointed out above, the narcosis should not be deep until the abdomen is opened, as it is important that the larynx should maintain its sensitiveness until the obstruction and incident back pressure are removed.

Pus, blood, or other fluids.—During operations for the relief of pulmonary or hepatic abscess, hydatid cysts, or of empyema, the patient may expectorate or otherwise expel large quantities of pus, blood, or other fluids, daughter cysts, etc., from the seat of disease, and these may, unless care is taken, pass again into the air-passages. As a rule, patients clear their lungs of accumulated secretions in the early morning, and soon after this is the safest time to administer the anæsthetic. Similarly, extensive hæmorrhages from phthisical vomicæ may occur, and lead to intense dyspnœa. Beyond being prepared for such emergencies, and maintaining so slight a narcosis that the patient does not lose his power of coughing up the intruding material,

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* There is a similar danger while artificial respiration is being performed. Undue pressure made upon the abdominal contents may induce expulsion of the fluids contained in the stomach and intestines, and thus the efforts to produce expiration may pump vomitus into the pharynx, and those of inspiration aspirate it into the air-passages.

little can be done. Posture is of much importance, and, as has been pointed out, the sound lung should be kept uppermost, and the patient should lie upon the diseased side. Artificial respiration performed by the usual methods is extremely dangerous in these cases, as it pumps the fluids into the pulmonary lobules, and eventually asphyxiates the patient. The " Schäfer " method, which is described below, is less open to this objection, and may be employed in these cases. Aspiration, perflation with oxygen, aided by compression of the sound side of the chest between the hands, one placed on the back and one in front, offer the best hope of assisting the patient to expel the foreign material from his air-passages. Partial inversion may also assist.

Overdose.

All general anæsthetics eventually **paralyse** the **respiratory centre.** Some act more rapidly, or if the vapour inhaled is too strong it may induce spasm of the glottis. When spasm is excited no air enters the lungs, but irregular thoracic movements persist. Spasm of the larynx certainly may occur during the use of ethyl chloride, ethyl bromide, ether, or chloroform vapour. It is stated that nitrous oxide gas may, in the presence of anox-æmia, excite laryngeal spasm. Cases occur in which the patient, either through the pungency of the vapour inhaled, or because some of the anæsthetic vapour may have become condensed and so comes in contact with the laryngeal mucous membrane, coughs with extreme violence, expiration becoming weaker and weaker, and inspiration ceasing. This state culminates in spasm of the glottis, cyanosis, and urgent dyspnœa. Spasm may arise not only from an overstrong vapour, but as a result of gradual asphyxia. The patient's colour will become pro-gressively more and more dusky, the lungs will be imperfectly ventilated, and the right heart over-distended. Spasm of the larynx then occurs, and the respirations become anarchic and cease, deep cyanosis supervening.

To treat this complication the head must be extended ; the tongue seized and drawn rhythmically forward, while pressure is made upon the *lower* ribs. Oxygen inhalations will often relieve the spasm, and should be given as soon as the spasm is sufficiently

relaxed to permit the gas being inspired. As a rule the spasm passes off rapidly, but it may be sufficiently severe to need laryngotomy. Phosgene gas, the result of the decomposition of chloroform, may cause laryngeal spasm.

· Chloroform also acts upon the larynx in another way, whereby the air-passage becomes occluded—namely, by the closure of the arytæno-epiglottidean folds (Lister). In this case respiratory movements persist, although no air enters the chest.

Patients may be actually asphyxiated by the anæsthetist excluding all air ; and this may occur with any inhaler, unless care is taken, and unless the colour of the face is watched.

The sighing and sobbing breathing of children is prone to lead to overdosage. Even when the induction of anæsthesia has been normal, gradual overdosage leading to enfeebled respiration will ensue unless the anæsthetist regulates the depth of narcosis. The full breathing of the stage of stimulation gradually passes off, the eyeballs under chloroform become fixed, and the conjunctival reflex is lost. Light reflex grows less active, and, blood-pressure having fallen, the pulse is weaker. These signs taken together indicate **profound narcosis.** It is then necessary, in order to avoid overdosage, to lessen the amount of anæsthetic, and to give air more freely, or even to withhold the anæsthetic altogether for a breath or two. Pallor, fall of blood-pressure, halting respiration, with returning conjunctival reflex, and a moving eyeball, associated with swallowing movements, indicate **lightening narcosis,** and the probable supervention of vomiting. In this case, unless the patient is very feeble, the treatment required is to increase the strength of the anæsthetic, always provided that it is known that the stomach is empty. These parallel conditions require great care to avoid making a mistake, since doing so may lead to fatal consequences.

Another aspect of overdosage, and one of great importance, is that in various conditions the respiratory centre is dulled and does not respond with its normal acuity to stimulation. The result is that respiratory compensation is diminished, the oxygenation of the body is dangerously lowered and asphyxia produced. Such states as anæmia, toxæmia, declension of the carbon dioxide in the blood, are examples of this condition. The gradual increase of duskiness and supervention of cyanosis give evidence of such a happening, and call for prompt artificial lung ventilation or perfusion. Feeble heart conditions may

also cause this weakened respiration, and demand special attention to the circulation by posture and so on.

Cyanosis which is due to respiratory embarrassment should be watched for, and remedied by giving air or oxygen. Feeble breathers will often become slightly blue even when inhaling low percentages of an anæsthetic. If the respiration is not stimulated by fresh air, it will grow weaker and finally cease, although prompt recourse to artificial respiration will restore it. This increasing feebleness of respiration should never be allowed to pass unnoticed or unrelieved.

Patients who are very nervous, especially if they have repeatedly taken anæsthetics, will sometimes voluntarily hold their breath, and may in this way produce serious asphyxial symptoms.

Treatment of conditions causing **interference** with **respiration**.—When a foreign body is lying free near the upper opening of the larynx, the tongue should not be pulled forward, otherwise the foreign body, especially if it is a tooth lying on the back of the tongue, may enter the trachea, since tongue traction, by pulling forward the epiglottis, leaves the larynx unprotected. If the foreign body can be felt to be fixed, its removal must be attempted with laryngeal or œsophageal forceps, or with a snare. When the obstruction cannot be reached with the finger the patient should, if sufficiently conscious, bend with his head very low, breathe air softly, and expire or cough forcibly while his back is slapped. This often causes the foreign body to be expelled. These measures failing, the patient should be inverted, with the view of dislodging the foreign body, although, of course, this procedure may set up laryngeal spasm due to the foreign body impinging upon the vocal cords from below. When this does not succeed, and if suffocation be imminent, laryngotomy must be performed. When the glottis has become occluded by the *falling back of the tongue*, pushing forward the lower jaw, so that the lower teeth lie in advance of the upper, will, by carrying the base of the tongue and epiglottis forward, open the air-passage. This is best done by pushing the angle of the jaw forward, at the same time depressing the chin to prevent the lower teeth engaging behind the upper ones. Considerable interference with respiration may arise from the lips closing upon the teeth. Inspiration under these circumstances cannot occur, although a certain amount of expiration is carried on. The

same obstruction often occurs in edentulous persons, the lips being drawn in and acting like an expiry valve. Nasal stenosis is a common cause of this difficulty, and relief may be obtained by opening the mouth, and inserting a gag between the teeth or gums. There is sometimes spasm of the jaw muscles, especially of the masseters, associated with the condition, and some difficulty may be encountered in the attempt to open the mouth. There is usually a gap in the line of teeth so that a gag can be introduced, and the mouth partly opened. When a gag cannot be introduced, a catheter attached to the oxygen-supply can usually be passed through a gap in the teeth and oxygen delivered over the opening of the larynx. The catheter can be introduced through the nostril if it cannot be got between the teeth. As soon as the mouth can be opened, the tongue should be pulled forward. Since the spasm is really asphyxial, it is as a rule relieved by such expedients, and the more drastic measure of opening the trachea can thus be obviated. In persons with thick necks, and in cases of angina Ludovici, the anatomical conditions cause dyspnœa and cyanosis. Such cases should be treated on similar lines, although in the last case laryngotomy may be extremely difficult, and perflation through a catheter passed through the larynx offers a more hopeful chance for the case.

The position in which the head should be placed while these measures are being carried out is of some importance. That which promotes the greatest freedom of breathing is the one which is required, and this varies in individual cases, and can readily be found by changing the pose of the head.

Dr. Benjamin Howard has advocated the method of placing the head in extreme extension in order to obtain the maximum degree of patency of the upper air-passages during narcosis. Professor Wood, however, contends that a better plan is to place the index fingers of each hand on the cornua of the hyoid bone, and the middle fingers against the angles of the jaw. The fingers should press forward and upward, thus extending the head on the neck and so opening the glottis. If this does not succeed, he recommends fixing a tenaculum far back into the base of the tongue and drawing it forward. I have found that lifting the hard palate with the forefinger of the right hand, while the tongue is hooked forward with the left forefinger, gives an extremely good air-way.

It should be remembered that when a patient is coming out of chloroform, and is about to **vomit**, the **glottis becomes closed**, and this may cause marked cyanosis. However, this state is at once relieved by the act of vomiting, and calls for no special treatment. In delicate subjects, this closure of the glottis is, however, liable to be associated with marked circulatory depression, in some cases leading to actual syncope.

When **spasm** of the **larynx** results from inhaling an anæsthetic, and persists after drawing forward the tongue and hooking up the larynx, laryngotomy must at once be performed. No formal operation is necessary·; the crico-thyroid membrane is incised, and a laryngotomy tube inserted. It is suggested by some that inhaling chloroform relaxes the spasm ; but this plan is of course useless if the rima is quite occluded, and its adoption may involve loss of valuable time.

Ether vapour if too concentrated may set up some laryngeal · **spasm.** This condition, although causing alarming dyspnœa, does not as a rule require any heroic treatment. Drawing the lower jaw smartly forward so that the lower teeth advance beyond the upper, and withdrawal of the vapour, are, as a rule, all that the complication demands. I have met with several cases in which alarming symptoms have followed spasm of the glottis during ether inhalation. It arose, I believe, from condensed vapour impinging upon the vocal cords. Dyspnœa and violent coughing are the symptoms ; the patient becomes dusky and even deeply cyanosed, and no air enters the lungs. This danger arises during the induction period, and can be usually successfully combated by traction on the tongue and oxygen inhalation. I have never been compelled to open the trachea to remedy this complication.

If, after the upper air-ways have been cleared and rendered patent by the manœuvres mentioned above, the breathing still remains unsatisfactory, artificial respiration must at once be practised by one of the following methods. There should be no delay in adopting artificial respiration ; all other measures are subsidiary, and although these need not be neglected, yet time should never be wasted, since lung ventilation must be obtained. Artificial respiration not only eliminates the anæsthetic vapour from the lungs, but promotes the passage of blood through the pulmonary circulation, and prevents heart-block. Before its adoption two essentials are : (i) an open air-way ;

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(ii) a posture which ensures the favourable position for free respiration and assists in the passage of blood to the head.

ARTIFICIAL RESPIRATION.

1. The Schäfer Method.

Sir Edward Sharpey Schäfer,* who has investigated the relative efficiency of various methods of performing artificial respiration, finds that the following gives the fullest pulmonary ventilation and offers the best chance of ejecting fluids which have entered the lungs. The method cannot be adopted in

Fig. 81.—Showing the position to be adopted for effecting artificial respiration (Schäfer's method).

all cases of suspended respiration under anæsthetics, since it involves placing the patient upon his face. I quote Sir Edward Schäfer's own description of his method:

" To effect artificial respiration, put yourself athwart or on one side of the patient's body in a kneeling posture and facing his head (see fig. 81). Place your hands flat over the lower part of the back (on the lowest ribs), one on each side, and gradually throw the weight of your body forward on to them so as to produce firm pressure—which must not be violent—

* See *Report of Committee Roy. Med. Chir. Soc.,* 1904, vol. lxxxvii. ; *Proc. Roy. Soc. Edin.,* vol. xxv., part i., p. 39.

upon the patient's chest. By this means the air (and water,
if there is any) is driven out of the patient's lungs.   Immediately
thereafter raise your body slowly, so as to remove the pressure,
but leaving your hands in position.   Repeat this forward and
backward movement (pressure and relaxation of pressure) every
four or five seconds.   In other words, sway your body slowly
forwards and backwards upon your arms twelve to fifteen times
a minute, without any marked pause between the movements.
This course must be pursued for at least half an hour, or until
the natural respirations are resumed.   If they are resumed,
and, as sometimes happens, again tend to fail, the process of
artificial respiration must be again resorted to as before."

2. SYLVESTER'S METHOD.*

For this method the patient is placed flat upon his back
with the head somewhat lower than the abdomen, and care
taken that there is no mechanical obstruction to the entrance
of air—*e.g.* falling back of the tongue, blood-clot, mucus, or
vomit in the pharynx.

Wilson † agrees with Dr. Bowles that during the performance
of artificial respiration it is best not to have the mouth widely
open, and the tongue dragged far out of the mouth.

The whole jaw should be pushed forward, the neck being
kept fully extended.   There should be no strain on the chest,
and so the head should not be allowed to hang back over the
end of the table.   The operator stands behind the patient
and grasps the arms *near* the elbows in such a way as to evert
them and render the pectorales majores tense.   He first presses
the arms into the sides, so as to compress the thorax and expel
air,‡ whilst at the same time an assistant should make pressure
upon the abdomen to prevent the increased intrathoracic
pressure from forcing down the diaphragm.   Next, he draws
the arms away from the sides, everting them and lifting the

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* The method described is modified by the introduction of the essential
features of the plans proposed by Pacini and Bain.

† *Trans. Soc. Anæsth.*, 1898, vol. i., p. 35.

‡ It is most important in chloroform cases requiring artificial respira-
tion that *expiration* be performed before inspiration, in order that the
chloroform-laden air in the lungs be forcibly expelled before fresh air
enters.

trunk of the patient as the arms become about 45 degrees beyond a line running through the body axis ; finally, he carries the arms up and back to a line parallel with the trunk. He pauses to allow air to rush freely into the lungs, and then brings the arms down to the sides as before. This process he repeats

Fig. 82.—Artificial respiration—Expiration.
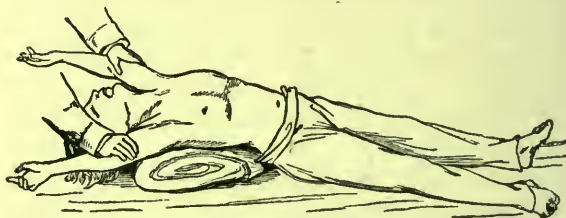
Fig. 83.—Artificial respiration—Inspiration.

twelve or sixteen times in one minute. The way the arms are grasped is important. When they are held *below* the elbows, it is not possible to open out the chest as effectively as when the plan just described is followed.

The diagrams given above illustrate this method of inducing artificial respiration.

3. Howard's Method

can be usefully employed, in conjunction with Sylvester's. It is also of value when the patient's chest is rigid. It is essential that the head should be extended on the trunk, so that the air-ways may be thoroughly straightened out. The patient is between the operator's knees. The latter, who faces him, applies his hands so as to grasp the free margin of the thorax, his thumbs resting upon the xyphoid cartilage. The operator presses upwards and inwards towards the diaphragm, gradually

bending over the patient, so that the weight of his body aids in compressing the thorax. After steady pressure for some seconds, with a sudden push up the operator throws himself back, then the resiliency of the chest walls will induce an inspiration. The process is repeated twelve or sixteen times a minute.

4. MARSHALL HALL'S METHOD.

Dr. Bowles, whose valuable researches made him an authority on the subject, has pointed out that in all cases when fluid has entered the lungs this method is valuable and superior to the Sylvester method. It is performed as follows : The patient is placed upon his face, his thorax resting upon a folded pillow ; pressure is made upon his back to produce expiration ; he is then rolled on to his side ; the weight is thus taken from the ribs ; they rise, and the lungs expand, thus causing inspiration ; the trunk is then again rolled into the prone posture, and this produces expiration. Expiration should be effected before inspiration. This is repeated slowly about fifteen times a minute.

In performing artificial respiration, the force used must be carefully regulated, as it is easy to fracture ribs, especially if the patient is old and his ribs are brittle.*

When the chest is markedly emphysematous, very little alteration in its capacity can be effected by Sylvester's method, and then either Schäfer's or Howard's must be relied upon, since in these the diaphragm is more efficiently brought into play. These systems are also applicable when, as sometimes happens, the patient has lost one or both arms. Laborde's method of tongue traction (see p. 427) is a valuable adjuvant to these systems of artificial respiration.

All measures in artificial respiration must be adopted quietly, firmly, and slowly, since crowding, hurry, fuss, and inexpertness are very dangerous. Life may be restored after even an hour's artificial respiration.

Faradisation of the phrenic nerves by poles placed, one on the external border of the sternomastoid muscle, and one on

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* I know of a case in which eleven ribs were fractured during the use of Howard's method. The manipulator was a powerful, heavy man and a medical resident in a hospital.

the thoracic attachment of the diaphragm, is regarded by some authorities as of great value. Personally, I consider it inferior to artificial respiration and to be fraught with danger.

FORCED ARTIFICIAL RESPIRATION.

Professor H. C. Wood regards all methods of artificial respiration as imperfect and inferior to the following plan * : A pair of bellows has a length of indiarubber tubing attached to it. A face-mask and two intubation tubes of different sizes are also in readiness. In the tubing " there should also be set a double tube, with an opening similar to that commonly found in the tracheal cannula of the physiological laboratory, so that the operator can allow the escape of any excess of air thrown in by the bellows." Professor Wood gives the following directions for employing the apparatus : " In using this apparatus, the mask should be first tried, care being exercised to see that the tongue is well drawn forward and held in place by a thread through it, and that the glottis is kept open." If the face-piece does not succeed, intubation should be at once performed. In the use of either the face-piece or of intubation, the lungs should be slowly but thoroughly expanded by each stroke of the bellows. Care must be taken that only sufficient force is used to expand, not to rupture, the air-vesicles. The addition of oxygen to the perflating air greatly enhances the value of the method. The patient's body temperature should be maintained. Forced respiration is of especial value for persons with rigid chests. The methods of intratracheal insufflation given below are undoubtedly more effectual than Dr. Wood's simpler procedure, but as the latter needs no complicated apparatus, it is applicable when an insufflation apparatus is not at hand.

Insufflation may be conducted by various methods, (1) the best being an apparatus such as that of Dr. Meltzer or one of the intratracheal ether insufflators described above (pp. 185 *et seq.*). It can also be effected in the following ways : (2) through a tube passed through the larynx into the trachea (intubation), as in the method of forced respiration detailed above ; (3) by mouth to mouth, an imperfect plan, but one of value when no bellows are at hand, and especially so in the case of children ; (4) through one nostril. Sir Edward Sharpey Schäfer tells me

* See " Therapeutics," ninth edition, p. 159, footnote.

it is easy to perflate both lungs by means of a catheter, passed through one nostril so that its distal end approximates to the opening of the larynx, and a pair of bellows, and he regards the plan as being of great value.

II. Accidents connected with the Heart and Blood-vessels.

The most serious accidents are those connected with the circulatory system. The effects of hæmorrhage have been already discussed above.

. **Faintness** or **syncope** may be caused by fright before anæsthesia is established, or may arise as the result of prolonged operations involving shock or profuse hæmorrhage, or may be occasioned by the entrance of air into a vein. The gravity of the accident depends upon the various circumstances : In lesser degrees attention to posture, *i.e.* lowering the head, and the maintenance of respiration will lead to the patient's recovery. Rubbing the lips with a cloth and flicking the chest with a wet towel will assist. The really serious cases are less hopeful, since the heart or the controlling nerve centres may have been paralysed by the action of the anæsthetic.

It will be best to describe the causes of circulatory failure in detail, leaving for the moment the question of treatment. Although syncope may occur under any anæsthetic, and has been recorded as taking place under nitrous oxide, ethyl chloride, ethyl bromide, ether, chloroform, and the many mixtures and solutions of these agents, yet the most serious cases are those which arise when chloroform is being inhaled. Clinically the respiratory and circulatory failure are associated. The mechanism by which this failure is brought about has been described in the chapter dealing with chloroform ; it only remains, therefore, briefly to enumerate the points which will enable the reader to recognise the bearing of the line of treatment suggested. Even a **few inhalations** of a **strong percentage** of **chloroform** may **paralyse the heart,** either by exciting vagal inhibition or by direct action upon the heart muscle (Embley and Martin ; Sherrington and Sowton). When respiration is interfered with, through whatever cause, the heart's action is hampered, the nervous control is seriously threatened, and even small quantities of chloroform may lead to serious or even fatal complications.

Under any percentage of chloroform the blood-pressure falls. Its fall is gradual so long as respiration is unaffected and no intercurrent complications such as hæmorrhage or asphyxia occur. In prolonged operations, especially if the anæsthetic has been given at all freely, this fall of blood-pressure becomes more serious, and syncope may supervene. The appearance of the patient is typical : he becomes pale and slightly dusky ; the pallor is best seen in the ears, lips, and beneath the nails ; breathing becomes slow and shallow; the eyeballs are fixed, the light reflex is sluggish or absent, and the pupils tend to dilate. Unless the condition is relieved, cyanosis soon appears ; breathing ceases or is represented by a few ineffectual gasps ; the radial pulse is lost, but faint heart movements can be felt, and heard by auscultation. A sudden fall of blood-pressure may occur quite early in narcosis, especially in young delicate children. It seems to be due, either to their inhaling an unduly strong percentage, or to the onset of vomiting. Even if the latter cause is the occasion of the pallor, it is unwise to push the anæsthetic, as children in this condition are easily overdosed.

When chloroform is given intermittently, and the patient is not fully anæsthetised, ventricular fibrillation may occur and death result. This is not strictly overdosage, but is due to a faulty method and incomplete anæsthesia. So far as is known, this condition is not met with except in the case of chloroform.

In combating the dangers of the fall of blood-pressure, it is most important to bear in mind the condition of the patient's organs at the time of inhalation. If, for example, the heart is fatty and its action feeble, if the respiration is hampered by old-standing lung disease or pulmonary œdema, the risk of even a slight fall of blood-pressure is enhanced, and it is necessary to restrict the percentage of chloroform from the outset of the administration. The most dangerous period of narcosis, as far as the circulation is concerned, is the induction. Struggling, so common in this stage, at once hampers respiration, interferes with the action of the heart, and leads to an irregular intake of chloroform. Holding the breath produces like results ; as a consequence a vicious circle is engendered, the heart fails to empty itself, and the respiration is inadequate, so that accumulation both of chloroform and of carbon dioxide occurs in the blood-stream, and the necessary elimination of these from the tissues cannot occur.

Although **diseased conditions** of the **heart** and **blood-vessels** as such seldom, if ever, constitute an insuperable objection to the giving of a general anæsthetic, they may produce dangers. A feebly beating fatty heart, and a dilated heart without compensation, are liable to become exhausted and to fail if overstimulated. I regard this danger as even greater than that arising from depression, always provided the blood-pressure is maintained. If depression ensues from giving an excessive strength vapour of chloroform or ethyl chloride, the anæmia of the medullary centres and failure of the coronary circulation will cause syncope, and **inversion** with **artificial respiration** are called for. If, on the other hand, excessive stimulation has been practised, the heart will stop and there is little hope of recovery. In the same way struggling and acapnic conditions will lead to heart failure. The employment of oxygen associated with carbon dioxide has been suggested by Dr. Yandell Henderson and Dr. Levi, of Florence, and may prove of value in such cases, although heart massage (see below) offers the best hope of saving the patient.

Aneurism.—In what I believe to be a unique case * an aneurism burst into the pericardium during anæsthesia, and mechanically produced heart stop. If heart massage had been attempted, it seems probable that the condition, which otherwise could hardly have been recognised, might have been detected and possibly relieved by surgical procedure.

Again, in **diseased conditions of the arteries** two main dangers arise. In cases of excessive blood-pressure due in part to arteriosclerosis, and in part to stimulation by the anæsthetic, possibly associated with struggling, rupture of one of the arteries of the brain may occur. This accident has been reported with nitrous oxide, with ether, and ethyl chloride, and may prove fatal. The treatment can only be conducted upon general principles, although bearing the danger in mind, prophylaxis, *i.e.* avoidance of struggling, of asphyxial complication, and of excessive stimulation, may prevent the danger. The second accident arises from the detachment of clot from the sac of an aneurism and consequent embolism and infarction. I have repeatedly administered an anæsthetic to persons who suffered from aneurism, and have only once met with this accident. In this case the anæsthetic used was ether, and this I now

* *Trans. Soc. Anæsth.*, vol. ix., p. 6, Dr. A. M. H. Gray's case.

consider to be not a generally suitable choice; the sac of the popliteal aneurism filled with clot and so was spontaneously cured. No later complications occurred. In phlebitis and " white leg " there is a similar danger, and here prophylaxis, rather than subsequent treatment, is the best protection of the patient's life.

Treatment of circulatory feebleness.—This necessarily varies, according as the patient is suffering from a slight fall of blood-pressure, or has inhaled an overdose of the anæsthetic. If the condition is mere faintness, cease the anæsthetic, lower the head, apply nitrite of amyl or ammonia fumes to the nostrils. The ammonia, if too strong, causes spasm of the glottis ; smelling salts, if at hand, will give the required stimulus to breathing. The chest may be compressed by the hand, and oxygen given by inhalation, but the tube must be held over the glottis. Dr. W. H. Willcox * advises the inhalation of oxygen which has bubbled through absolute alcohol. A cylinder of oxygen delivers the gas into a Wolffe's bottle containing absolute alcohol. The inlet tubes are placed below the level of the alcohol, and the gas takes up 4 per cent. of the alcohol and traverses tubing to which is attached a glass funnel from which the patient inhales. The more rapidly the oxygen bubbles through, the more alcohol reaches the patient. This procedure is based upon the experiments undertaken by Professor B. J. Collingwood in 1909–10, which demonstrated that in cases of poisoning by chloroform, after respiratory failure and profound circulatory weakness, oxygen carrying alcohol vapour was able to restore respiration and circulation. The patient should be placed supine, his legs and arms raised, and his head dropped below the level of the trunk, partial or complete inversion being of the greatest value in syncope during narcosis. The maintenance of regular respiration is of the greatest importance in all cases of syncopal seizure, and to this end artificial respiration must be practised at once. Rubbing the inside of the lips with brandy is of marked value in these cases. An enema of brandy—℥ss. in ℥ij. of hot beef-tea or gruel or starch—may be tried. When the patient has recovered sufficiently to swallow, hot strong coffee with a teaspoonful of cognac should be taken. The most stringent injunctions must be given that the horizontal posture be maintained until the heart has quite recovered itself. Many

* *Lancet,* 1920, vol. i., p. 497.

authorities advise the injection of Liq. strychninæ, ℳiv. or ℳv.
being introduced under the skin, and this procedure is of value
when respiration is feeble and when the cause of the fall of blood-
pressure is not shock.

In graver cases.—When the above symptoms do not yield to
such treatment, or if the condition of the patient is obviously
very serious *ab initio*, complete inversion with vigorous artificial
respiration, or, still better, forced respiration (intratracheal
insufflation) with oxygen must be adopted. Bandaging the
abdomen is certainly valuable, and should be adopted when
the blood-pressure has fallen. Rectal injections of hot water
or saline are of undoubted utility. The treatment rehearsed
above also applies to these cases ; in them it is usually more
common to find a *gradual heart failure* occurring, and giving
warning of trouble. Respiration is also liable to flag at the same
time as the heart fails. It is especially necessary, therefore,
to have resort to artificial respiration early, both on this account
and because that measure, even by itself, will frequently steady
the heart and restore its rhythm. Maas's method of rapid
percussion over the cardiac area has been already noticed.

Although **artificial respiration** with **inversion** and the direct
action of kneading the heart by **cardiac massage** are the really
important procedures, efforts may be made to assist circulation
by various subsidiary means. Of these, hypodermic injections
of such drugs as strychnine, pituitary extract, and digitaline
are in common use. Strychnine in gr. $\frac{1}{30}$ doses is of some value
in respiratory depression with general circulatory feebleness,
but should be avoided when there is reason to believe that the
nerve controls are exhausted. The pituitary extracts * are the

* Pituitary extract is made from the posterior or infundibular lobe
(hypophysis) of the pituitary gland of cattle. Twenty parts of the finely
minced fresh gland are treated with sufficient saline solution to produce
100 fluid parts. To the resulting extract a small proportion of phenol
is commonly added as a preservative, and the product is sterilised and
preserved in sealed sterile glass containers. Ampoules of ½ c.c. and
1 c.c. are obtainable. The activity is tested physiologically, one stan-
dard being that 10 minims, when injected intravenously into a cat of
2,500 grammes, should raise the blood-pressure at least 20 mm. of mercury.
Measurements of the uterine contractions induced are also made. It is a
transparent liquid, colourless or almost colourless, and having a faint
characteristic odour. The Liquor Hypophysis of the United States Phar-
macopœia is a similar preparation made with slightly acidulated water.
It is required to be of such a strength that 1 c.c., when diluted 20,000

most powerful vaso-motor constrictors, and, although their
effect soon wears off, are of undoubted value. Hypodermic
injection of sparteine sulphate gr. $\frac{1}{2}$, or oxysparteine (Langlois
and Maurange) is of service in averting heart failure under
chloroform. Transfusion of normal saline has been used suc-
cessfully in cases of syncope associated with severe hæmorrhage
under anæsthetics. The saline solution may be introduced
directly into a vein, or infiltrated through a cannula into the
cutaneous tissues of the thigh or arm. The gum arabic (Bayliss)
saline is probably more efficacious than normal saline, and
should be always in readiness. The use of intravenous infusion
of saline is, I think, the most valuable of all the subsidiary
means of treating collapse due to shock under anæsthetics
when this is not due to overdosage.

Acupuncture of the heart.*—In a series of careful experiments
Dr. B. A. Watson has shown the utility of puncturing the right
ventricle in cases of heart failure under chloroform. It is possible
by this plan to remove the excess of blood from the overtaxed
heart, and at the same time a mechanical stimulus is applied
to the myocardium. The plan has been tried in the case of
human beings, but I believe without conspicuous success.

Direct Massage of the Heart.

The heart muscle may not respond to puncture, but it is well
known that, when subjected to direct manual manipulation, it
is capable of expelling its contents and resuming its normal
rhythm. Guided by this physiological fact, Prus † originally
suggested a plan by which the surgeon could gain access to
the heart, in cases of cardioparesis under anæsthetics, and excite

times, produces the same effect on the isolated uterus of the virgin
guinea-pig as a 1 in 20,000,000 solution of β-iminazolyl-ethylamine hydro-
chloride. Extracts of the posterior lobe of the pituitary body cause a
persistent rise of blood-pressure, a slower and stronger heart-beat, con-
traction of the uterus, and increased secretion of urine. $\frac{1}{2}$ or 1 c.c. may be
administered subcutaneously, but as this may cause superficial slough-
ing owing to local vaso-constriction, it is preferable to inject intramuscu-
larly. When rapid action is required, it may be given intravenously in
normal saline solution.

* See a useful paper by Dr. B. A. Watson, *Trans. of Amer. Surg. Assn.*,
May 13, 1887.

† *Hospitalstidente*, 4 Roekke, Band viii., No. 47, R. Kier-Peterson.

it to renewed activity. His operation, which involved a formal and prolonged surgical procedure upon the thorax giving access to the pericardium by resection of portions of the third and fourth ribs, has been superseded by simpler methods. Various operations by the thoracic route have been devised. The **thoracic method,** involving as it does a resection of the thoracic parietes and exposure of the pericardium, causes much shock, and often injures the arteries and nerves in the area involved, besides leading to the creation of pneumothorax. The results have not been satisfactory. Dr. Babcock's operation obviates some of these objections and has given better results. It is described above (p. 302).

The **abdominal route** is the better procedure. When the abdomen is open, as during an abdominal section, no formal operation is required unless the diaphragm is opened, and massage may be started at once. If, as often happens, the operation has not been attempted, the most rapid plan is to make an epigastric incision *; the apex of the heart is then held between the thumb and forefinger and compressed rhythmically thirty or forty times a minute, while artificial respiration is kept up. The heart massage should not be finally desisted from until respiration has become normal. This plan is certainly the one which involves least trauma, and obviates loss of valuable time. It is important to make the abdominal opening sufficiently large, so as to prevent the hand of the operator becoming cramped during its performance of the massage movements. J. C. Bost † makes an incision four inches long from above the umbilicus well into the xipho-sternal notch. Good exposure is obtained by placing a pillow under the waist of the patient and retracting strongly the left costal cartilages. Another incision two inches long is made one inch to the left of the median line outwards behind the costal margin, cutting the fibres of the diaphragm near their insertion. The pleural cavity is opened by a blunt instrument, afterwards two or three fingers are introduced to stretch the tissues and allow of the insertion of the right hand in front of the peri-cardium. The hand is passed upward, the thumb behind

* See the Bradshaw Lecture by Sir Charles Ballance, K.C.M.G., C.B., *Lancet*, Jan. 10, 1920, p. 75.

† " A New Technique of Heart Massage," J. C. Bost, M.D. Washing-ton, D.C., Temp. Capt. R.A.M.C., *Lancet*, Oct. 26, 1918, p. 553.

the sternum, while the fingers grasp the heart. The thumb can in this way knead both the auricles and ventricles. It is claimed for this plan that it does not injure the vessels, nerves, or other important structures, and that the incision can be effectively closed. Major Neve points out that in some cases, the subdiaphragmatic plan (*i.e.* when the diaphragm is not opened) fails, as only the apex of the heart can be grasped. This is obviated, and with slight additional risk or trauma, by the procedure described. Bost gives the details of a case which appeared hopeless, but in which the heart was restored to activity, although consciousness did not return and death occurred seventy-seven hours after the operation. Mr. L. E. C. Norbury,* on the other hand, deprecates the adoption of the transdiaphragmatical route. He contends that it involves loss of time, and has not been found ultimately successful in the cases in which it has been adopted. The question of time-saving is definitely an important one, since in several of the cases in which cardiac massage succeeded in restoring circulation for a time the patient ultimately died, having never recovered consciousness. It is an accepted fact that the brain tissues are damaged, and often irreparably so if deprived for even a short time of a sufficient supply of oxygenated blood. Automatic vital action, as in Prus's case, may be restored for some hours, but sentient existence is soon destroyed past recall. No case, so far as I am aware, has been resuscitated and has ultimately lived if the time in commencing heart massage has been delayed more than eight minutes. Nor does there appear to be any cogent reason for postponing the operation beyond a few minutes in which less severe measures have been tried, since it should not in itself add to the gravity of the patient's condition.

When sufficient access to the heart has been obtained, whatever operation is pursued, the heart is compressed between the finger and thumb, or by the whole hand, and kneaded rhythmically thirty or forty times a minute. Gentleness and firmness are necessary, and massage should be maintained for at least half an hour, even if no automatic cardiac movements occur. Artificial respiration must be kept up uninterruptedly throughout the massage, perflation with oxygen being the best method to employ. **Adrenalin should not be injected,** as it is liable to cause ventricular fibrillation. Crile adopts a more elaborate

* "Cardiac Massage and Resuscitation," *Lancet,* Oct. 4, 1919, p. 601.

technique consisting of cardiac massage and intravenous injection of saline containing 1 in 25,000 or 1 in 50,000 adrenalin, the use of the "pneumatic suit" to raise blood-pressure, and means to insure an artificial respiration. He has restored the circulation in a dog after it had been apparently dead for thirty minutes, by anastomosing its carotid artery to that of a living dog.

Many cases of cardiac massage have now been recorded, and recent statistics are much more favourable than were those of some years ago, for example, those given in Professor Keen's paper. One of the earliest cases occurred under ether, and was reported by Dr. Starling and Sir Arbuthnot Lane.* Ricketts † reported thirty-nine cases, in twelve of which the heart's action was restarted. In one case, ultimately successful, the heart's action had ceased for twenty minutes before it was resumed. The ages of the patients varied between 22 and 65. Dr. T. A. Green ‡ has studied the subject very carefully, and Dr. V. Orr has reported upon the matter.§ W. M. Mollison ‖ recorded a successful case in a boy of six, who had inhaled the C.E. mixture, but pituitrin had also been used. This writer quotes the literature of seventeen cases, some of the patients having had ether and some chloroform. L. E. C. Norbury ¶ has examined the theories on cardiac massage, and the methods adopted in resuscitation by this plan. His experience of fourteen to sixteen cases in which the subdiaphragmatic route was adopted, with three successes, leads him to prefer this method, since it saves time and causes little trauma. If the abdomen is not opened at the time of the failure of the heart, he makes a vertical incision in the left rectus and splits the muscle.

In a case cited by M. J. Petty, jun.,** the patient was unconscious for twelve hours after the resumption of normal cardiac function, although the period of anæsthesia was only five minutes. This was no doubt due to the damage done to the nerve structures during the 6¾ minutes during which the heart failed to

* *Trans. Soc. Anæsth.*, vol. vi., p. 27.

† *J. Amer. Med. Assn.*, 1906, quoted by Sir Charles Ballance in the Bradshaw Lecture, 1919.

‡ *Lancet*, Dec. 22, 1906.

§ *Proc. Roy. Soc. Med.*, Section of Anæsthetics, Nov. 5, 1909.

‖ *Ibid.*, Nov. 3, 1906.

¶ *Lancet*, Oct. 4, 1919, p. 601.

** *Ibid.*, Nov. 1, 1919, p. 784.

react. A further point of interest in this case is that a second heart failure occurred which was relieved by resumption of the massage. The patient was aged 54, and the anæsthetic was chloroform.

Appropriate Cases.— Dr. Green regards the following conditions as calling for heart massage : (1) Primary heart failure due to acute dilatation from an overdose ; (2) primary paralysis of respiration and the vasomotor apparatus arising from gradual accumulation of the anæsthetic, owing to prolonged slight overdosage ; (3) asphyxia causing overfilling of the right ventricle ; (4) failure of respiration and later of circulation due to exhaustion following shock or over-stimulation.

Such a classification is really more academic than practical, for there can be no doubt that any case of heart-stop occurring under an anæsthetic, which does not respond in four or five minutes to artificial respiration, posture, and the subsidiary measures pursued in such conditions, should be treated by cardiac massage. As a rule sudden heart failure, occurring as a reflex when an incompletely anæsthetised person is subjected to the knife, can be successfully dealt with by posture and pulmonary ventilation, but massage should be tried even for this condition if less active measures do not cause the heart to escape promptly from inhibition. From what we now know about cardiac surgery, it cannot be doubted that the operation for cardiac massage is not a serious one, nor does its performance imperil a patient's chance of resuscitation, while its neglect may deny him his one chance of escape from death. Certainly, when the abdomen is already open, there is no excuse for delay in employing massage.

Summary.—If heart failure occurs in any patient under an anæsthetic, artificial respiration should be started at once, and the patency of the air-passages ensured. Perfusion with oxygen is the most effectual method, the gas being warmed and moistened, and expiration and inspiration provided for. Inversion of the patient assists unless the heart is over-filled, as in asphyxia. These measures may be pursued for three or four minutes, and this time can be utilised in sterilising the abdominal skin and making preparations for the operation. Then the subdiaphragmatic operation should be quickly performed, and if the heart is found to be flaccid, full inversion of the patient should be obtained, and cardiac massage commenced, at first gently, later more vigorously. If the organ cannot

be satisfactorily grasped, the diaphragm should be divided by subcostal incisions parallel to the costal border, and the operator should insert his whole hand and grasp the whole heart between the thumb and fingers. The massage should be persisted in until natural cardiac movements have become established, and have attained sufficient strength to ensure an adequate circulation. Indeed, the natural contractions should be supplemented by gentle squeezes for a longer time if the breathing is unsatisfactory, until full pulmonary ventilation is performed without artificial assistance. Any subsequent tendency to heart failure should be met by renewed massage. Artificial respiration is in all cases at least as important as massage, and must be efficiently performed and persisted in. Pituitrin, strychnine, adrenalin are of doubtful value, and the last-named drug is probably dangerous.

AFTER-EFFECTS OCCURRING IN THE POST-ANÆSTHETIC STAGE.

These may arise as the result of faulty position, collapse from shock, and chilling of the body when the patient is carried from a hot operating theatre into a fireless bedroom.

Faintness and vomiting are dangerous in the case of a very asthenic patient; the danger may arise through a faulty posture, or if the patient is placed in such a position that he can roll over upon his face. There should always be an attendant to turn the head to one side, or, if it is necessary, to raise it, when vomiting occurs, so that the vomit may not be aspirated into the air-passages.

Collapse is best treated by heat applied to the patient's body, great care being taken that the hot-water bottles do not cause burns. When morphine or scopolamine has been given immediately before the operation or at its close, and before the anæsthetic effect has passed off, there is a danger of the development of deepening coma, enfeeblement of respiration, and circulatory depression.

In some cases it may occur that patients, who are apparently suffering but slightly from shock and in a light degree of narcosis at the close of a prolonged operation, become progressively more collapsed and profoundly unconscious within a short time. Their breathing becomes feeble, the pulse weak, and the skin cold; these symptoms may arise from surgical shock, but are

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as a rule due to unnecessary quantities of the anæsthetic having been inhaled and the incautious use of morphine after the anæsthetic. One of the dangers of ether arises from the collapse due to exhaustion of the nerve centres, which is apt to follow its stimulating effect pursued throughout a protracted operation.

When the amount of anæsthetic has been carefully kept within the necessary limits of the surgeon's requirements, and the strength of vapour employed has been also kept low, very little anæsthetic shock arises. It must be remembered that shock due to surgical procedures is evinced by fall of body temperature, declension of the blood-pressure, and exhaustion of the central nervous controls. When hæmorrhage occurs, when the blood-pressure is low, and when lung ventilation is diminished, leading to some degree of anoxæmia, very much less of an anæsthetic will maintain complete anæsthesia than is necessary when these phenomena are absent. Hence, as an operation proceeds, collapse and other evils may be prevented by gradually lessening the amount of the anæsthetic. That oxygen lessens shock and is altogether beneficial I have no doubt. Those who deny this, and even state that it is harmful, have adduced no experimental or clinical evidence of any value to support their *ipse dixit*. *A priori* arguments as against experimental research cannot be accepted. The condition must be treated by the application of heat to the body, rectal injections of warm saline, and the inhalation of warmed moistened oxygen.

Occasionally patients, especially after ether, become maniacal and require control. Maniacal seizures may follow the use of any anæsthetic, and indeed have ensued upon the use of analgesics, although they are rare. Usually the persons who are prone to them have a history of having been insane or extremely neurotic earlier in life. In the case of alcoholics such seizures seem to be of the nature of delirium tremens. I have given anæsthetics to a large number of persons whose minds were unhinged or who had been lunatics at some period of their lives, but I have never met with true mania as a sequela. Sir George Savage's views are that there is a distinct danger of recrudescence of mental trouble after an anæsthetic in the case of those who are predisposed to mental aberration.

Paralysis following anæsthesia.—Both central and peripheral paralysis may follow anæsthesia. The central form is due to

rupture or blocking of blood-vessels, the result of alterations of blood-pressure caused by anæsthetics. Thus **apoplexy**—a rare accident—has been recorded. Beyond attention to the posture of the patient, little can be done in such cases. The choice of the anæsthetic and method of administration should be guided by the necessity for avoiding struggling and any increase of blood-pressure, and for ensuring absolute freedom from asphyxial complication. These ends are best attained by using chloroform with oxygen from a Vernon Harcourt inhaler. Erb and others have pointed out that peripheral paralyses follow the use of anæsthetics, and are usually due to traumatism from pressure on nerves—for example, when the arm is allowed to hang over the side of the operating-table and the musculo-spiral nerve is compressed. Lateral decubitus has led to paresis in the arm upon which the weight of the body rests. The pressure of Clover's crutch also has, it is stated, caused paresis of the nerves of the leg and even damage to the popliteal vessels. Also the forcible extension of the arms upward may injure the brachial plexus. Functional paralysis also may follow anæsthesia. In all the aforesaid cases care in avoiding pressure upon nerves is the important matter: after-treatment may be carried out on general principles.

Glycosuria : diabetic coma.—Diabetics must always run an increased risk in taking an anæsthetic. The amount of sugar should be lessened by rest and treatment before the inhalation. If the glycosuria is pronounced and occurs in a young subject, a general anæsthetic should usually be replaced by spinal anæsthesia, although that method does not preclude the danger of the onset of coma. If a general anæsthetic is used, it should be strictly limited in quantity and given with oxygen. I am inclined to think that excessive stress has been laid upon the danger in the case of general anæsthetics. It is largely a question of the amount of the anæsthetic employed, but coma may follow the use of either chloroform or ether.

Post-anæsthetic poisoning (acidosis) is considered above (p. 307). It may, however, be further pointed out that the term "acidosis" as a specific description of a condition due to poisoning by anæsthetics must be relinquished. The lessening of the alkali reserve which occurs in some patients is not only an effect following an operation under an anæsthetic, but

develops whenever the metabolism of the organism is profoundly interfered with. Thus sudden change of dietary, severe purging, cyclic vomiting, lessened supply of ingested liquids, may cause acidosis. The visceral lesions closely resemble those due to sepsis, and certainly some of the cases attributed to delayed anæsthetic poisoning have been really due to septic intoxication. Imperfect or faulty preparation for the anæsthetic also accounts for some cases. It is possible that unsuspected sources of septicity, such as oral sepsis, may lead to the condition. Shock causing lowered blood-pressure, concentration of the blood, and exposure to cold, are contributary causes. Prophylaxis should be carried out with a view to combating these dangerous complications. The **treatment** to be adopted may be summarised : (i.) maintaining the body temperature ; (ii.) raising the blood-pressure; (iii.) checking the vomiting by lavage with alkaline fluids ; (iv.) rectal injections of saline containing glucose ; (v.) inhalations of warmed moistened oxygen. If morphine is used at all to check the urgent sickness, it must be with the utmost caution, and in as small doses as possible. The chief indication is to maintain the strength of the patient until the vomiting has ceased.

CHAPTER XI.

LOCAL AND REGIONAL ANALGESIA—SPINAL ANALGESIA.

LOCAL analgesia, that is, loss of sensation to painful stimuli, without the superinduction of unconsciousness, is obtained in the following ways :

1. By painting the skin or mucous membranes with solutions of the analgesic.

2. Injecting such solutions endermically or hypodermically.

3. Injecting solutions across or in the course of nerve trunks (conduction or regional), or into the sheath of the nerve trunk (neural), by intravascular injections.

4. Injecting into the subdural space or into the spinal theca (spinal analgesia), also injections made into the sacral canal (sacral analgesia).

5. By cold.

6. By electricity.

The application of solutions of analgesics by brushing, or by pledgets soaked in them, to the area of operation is unsatisfactory in so far as the skin is concerned, but absorption readily takes place by mucous or serous surfaces. Hence in ophthalmology, in laryngology, in rhinology, and in urinology such procedures are commonly employed.

The rapid progress which has been made in local analgesia is largely due to Dr. Heinrich Braun, who, employing solutions of analgesics with suprarenal extracts (adrenalin, suprarenin), has demonstrated that the method is of very wide application.

Professor Schleich undertook the pioneer work. As soon as cocaine was shown to be dangerous owing to its toxicity, he evolved the infiltration method, whereby a highly diluted solution was introduced, first into, and subsequently beneath, the skin, an artificial œdema being produced. The obvious drawbacks to this have led to the adoption of the present system, in which the area of operation is isolated from the central nervous

system by injections of an analgesic around the area, thus blocking the nerves in the field of operation ; or by injections made at some distance from the operation site into or about the nerve trunks, which are known to innervate the structures involved. The addition of adrenalin * leads to ischæmia, so that the analgesic introduced remains in the neighbourhood of the injection, and so the analgesic effect is increased and persists. Bier and others have, in the case of the digits, toes, and limbs, still further prevented this deportation by using constricting bands on the central side of the operation area. Bier has also suggested **injections** into **veins** in this isolated site in order to bring the anæsthetic or analgesic into the most intimate relation with the nerves. This procedure, and the more dangerous one of **intra-arterial injection,** are too complex to warrant their description in this place ; nor is it necessary, since with regional analgesia the same results are obtainable by less complicated methods.

Since regional analgesia implies the cutting off of a given area from the central nervous system, it is obvious that injections made either extradurally or intradurally about the sensory nerve roots of the spinal cord are really an extension of a common method, *i.e.* of regional analgesia. The results of extradural injections do not at the present time appear to compare favourably with those made directly into the theca, although M. Tuffier regards the method as of some value. An extension of extradural injection is the epidural method of Cathelin, in which the analgesic is introduced into the sacral canal and acts upon the nerves contained in that space.

The essence of success in applying these methods consists in an exact knowledge of the behaviour of the drugs which are employed. These drugs may be now considered.

The doses given in the following sections are applicable only to adults.

COCAINE.

Cocaine, $C_{17}H_{21}NO_4$, is an alkaloid occurring in the leaves of *Erythroxylon Coca*, and its varieties. Garnicke isolated erythroxylin in 1855, Niemann obtained cocaine from coca

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* Some confusion is liable to arise owing to the number of names given to the adrenal extracts. The term adrenalin is employed in the British Pharmacopœia to designate the natural product of the suprarenal bodies.

in 1860, and Karl Koller used it in surgery in 1884. Cocaine is only slightly soluble in water (about 1 in 1,300), but cocaine hydrochloride, $C_{17}H_{21}NO_4HCl$, is freely soluble (2 in 1), and it is this salt which is commonly used for aqueous solutions. The solutions should be made at the time of use. They cannot be boiled, since this destroys their analgesic properties. Many synthetic substitutes for cocaine have been suggested for use as local analgesics. They are known by the trade names of eucaine [B.P. benzamine], alypin, stovaine, anæsthesin, novocain, nirvanin, acoine, new orthoform, and holocaine. The most important of these are considered below.

Cocaine acts as a general anæsthetic when very large doses are taken. Its true action is analgesic, due not to the vaso-motor constriction which it establishes, but to its influence upon the sensory nerve endings. If an area is rendered anæmic and analgesic by cocaine, the subsequent injection of pilocarpine will abrogate the anæmia, while the analgesia remains unaffected. Arloing has shown the same thing by dividing the sympathetic of a rabbit on one side, the animal having been previously co-cainised—hypervascularity could thus be seen to exist simul-taneously with analgesia.

Physiological Action of Cocaine.

In **cold-blooded** animals, cocaine, whether applied to the heart itself, circulated through the detached ventricle, or in-jected into the circulation, slows the rhythm and depresses the beat, and finally arrests the heart in diastole. Its depressant action upon the heart is shown by the accompanying cardio-gram (taken by the author with Roy's tonometer) (fig. 84).

Cocaine also interferes with cardiac innervation, decreasing in a very marked degree the excitability of the nerves ; it abolishes " make " contractions, but " break " contractions per-sist. Although both auricles and ventricles are influenced, the latter are more interfered with, and cease to beat before auricular rhythm is arrested (Van Anrep).

The blood-vessels are but little if at all affected by cocaine, unless it be applied locally as a paint, and in this case it is doubt-ful how far the action is really characteristic of the drug.

In **warm-blooded** animals, an initial increase in rapidity of the heart's beat occurs, the heart's action is weakened, but
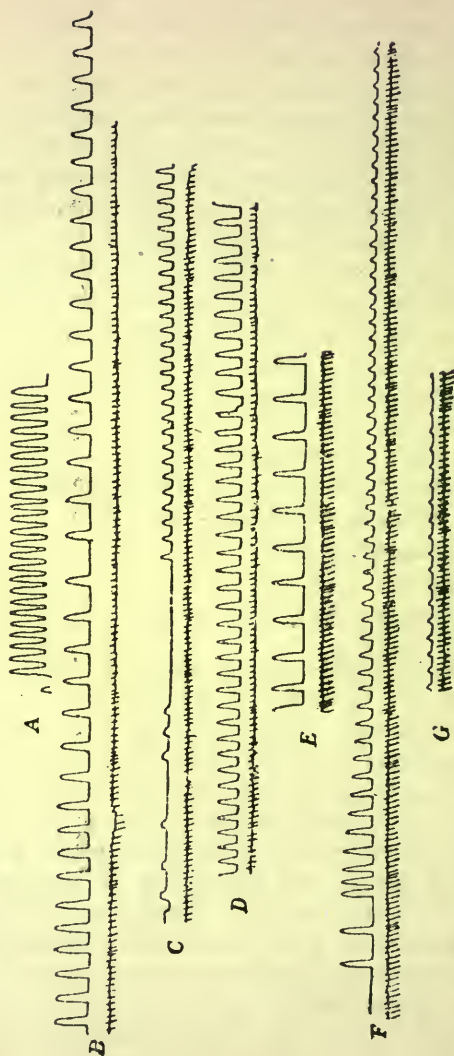
FIG. 84.—Cardiograms of frog's heart (effect of cocaine). *A.* Normal trace. *B.* After addition of cocaine to circulating fluid. *C.* Cocaine removed, nutrient fluid recirculated. *D., E.* Recovery to normal. *F.* Cocaine again circulated. *G.* Extreme heart failure, no recovery. Taken with a Roy's tonometer.

usually recovers and, it is said, survives the cessation of respiration (Van Anrep). Vagal inhibition is also much depressed and even lost ; blood-pressure is greatly lowered, although this is preceded by an initial and transient rise of pressure. Cocaine is a vaso-constrictor, and so produces some degree of local ischæmia after its injection.

Cocaine produces a very marked **depressing action** upon the **human heart.** Many persons, after even small doses, become pallid and complain of extreme faintness, while the heart's beat grows weak and irregular, the radial pulse becoming almost imperceptible. Cocaine in very large doses (and we must remember that what constitutes a large dose varies greatly among different individuals) renders the respirations more rapid, irregular and shallow, and finally asphyxiates by respiratory paralysis. In human beings, marked dyspnœa and breathlessness may follow its use.

Convulsions and epileptiform seizures, due, it is said (Durdufi), to vaso-motor irritation producing anæmia of the brain, occur after toxic doses. Death, according to Mosso, results from tetanic contraction of the diaphragm.

The nervous system is much affected by cocaine. The peripheral nerves of sense become anæsthetic over the area into which cocaine has been injected, the analgesia extending just so far as the drug traverses the tissues. When injected into a nerve trunk, it blocks the transmission of impulses. The insensibility wears off in time, and is followed by more or less severe " reactionary pain " (Struthers). When injected into the subarachnoid space analgesia of the lower extremities is produced, but is often associated with severe cephalalgia, and sometimes fatal results. Dastre very aptly terms cocaine the " curare " of the sense nerves. Painting over the skin produces no analgesic effect, but mucous membranes absorb the drug, analgesia resulting. The motor nerves are usually only affected by large doses of the drug, but in some persons comparatively small doses have induced paresis or paralysis, lasting for hours or even days. Ptyalism occurs, leading to dryness of the mouth and fauces. Peristalsis is increased and vomiting and borborygmi follow its use. The other secretions of the alimentary tract are lessened. The urea and phosphoric acid excretion is increased by it (Fleischer). Cocaine promotes destruction of tissue, and by a constant repetition of this process leads finally

to physiological ruin. Mydriasis and proptosis, in warm-blooded animals, follow its use. Cocaine causes also great hyper-excitation of the muscular system and marked agitation ; a large dose at first may simulate strychnine in its action, by producing muscular tremblings, convulsive movements and spasms.

Although the mind at first remains clear, there is usually a tendency to garrulity, followed by great anxiety and feelings of unaccountable distress. Languor, muscular weakness, and lassitude will then take possession of the patient, who becomes haunted by most fantastic hallucinations. Some persons simply experience slight elation, or it may be drowsiness, but loquacity is the most usual symptom.

The effect on the nervous system may be summed up in the words of Dastre, that while the drug paralyses the terminations of the sensory nerves, it excites initially all other parts—nerve trunks, spinal cord, medulla, encephalon, and the sympathetic chain.

Cocaine produces at first a slight rise in body temperature.

It is eliminated by the kidneys, and often produces albumi-nuria or glycosuria, which Van Anrep regards as the result of the partial paralysis of respiration.

Strong solutions cause much irritation and injure the tissues. The occurrence of local gangrene reported in the earlier years of its use was probably due to dirty instruments or im-purities such as moulds present in the solutions employed. As cocaine cannot be sterilised in solution and does not remain sterile if kept, the solutions should be freshly prepared before use.

The symptoms which characterise poisoning by cocaine are (1) enfeeblement of the heart, with a remarkable lowering of blood-pressure, paling of the skin and mucous membranes ; (2) great dyspnœic distress from failure of respiration ; (3) impair-ment of mental faculties and even unconsciousness, or in some cases catalepsy or convulsions, or a loss of movement in various groups of muscles. Perhaps the most serious danger of cocaine is its liability to induce a drug habit. Those who have had cocaine injected, or even applied to mucous membranes, experi-ence a feeling of pleasant exhilaration, and soon learn to repeat the application in order to renew the sensation.

The Dose of Cocaine.

This depends upon the concentration of the solution used, since, when much diluted, large doses of cocaine are more readily borne, and when adrenalin is added the toxicity of cocaine appears to be decreased. Reclus gives 0·097 grm. as the maximum in a 1 per cent. solution, 0·194 grm. in a 0·5 per cent. solution ; but this is probably too high an estimate. Braun limits the 1 per cent. solution to 0·0485 grm. and the 0·1 per cent. solution to 0·065 grm. Struthers regards 0·065 grm. as the limit in 0·5 per cent. solutions, and 0·13 grm. in the 0·1 per cent. solution when adrenalin is added to these solutions.

Benzamine (β-Eucaine).

Benzamine or β-Eucaine, $C_{15}H_{21}NO_2$, is a synthetic compound chemically allied to cocaine. The best known salts of the base are the hydrochloride and the lactate. β-Eucaine hydrochloride is a white crystalline powder, neutral or very feebly alkaline, and soluble in water 1 in 30. β-Eucaine lactate is soluble in water 1 in 5, and for this reason it has largely superseded the hydrochloride. The proportion of β-eucaine in the lactate is less than in the hydrochloride ; 100 grammes of the hydrochloride contain as much of the base as 119 grammes of the lactate. Solutions of the β-eucaine salts may be sterilised by boiling without decomposition.

α-Eucaine, $C_{19}H_{27}NO_4$, differs from β-eucaine in constitution, and is no longer used as an analgesic, since its solutions are somewhat painful and irritant when injected.

β-Eucaine solutions are used to produce local analgesia by infiltration with or without the addition of adrenalin. A 0·2 per cent. solution is commonly employed for this purpose ; it is made isotonic by the addition of sodium chloride.

Solutions made according to the following formulæ are exactly isotonic :

I.	β-Eucaine Hydrochloride	. . .	0·20 grm.
	Sodium Chloride	. . .	0·82 grm.
	. Distilled water sufficient to make	.	100·00 c.c.
II.	β-Eucaine Lactate	. . .	0·20 grm.
	Sodium Chloride	. . .	0·87 grm.
	Distilled water sufficient to make	.	100·00 c.c.

For every 100 c.c. of β-eucaine solution, 10 minims of adrenalin solution (1 in 1,000) are generally used, and it is advisable to add this *after* the solution has been boiled. β-Eucaine solutions should always be boiled in alkali-free glass vessels.

β-**Eucaine** resembles cocaine in its general behaviour. It is less toxic, and its action upon the heart is less depressant. It is a vaso-dilator, and diffuses less readily than cocaine. This drug has lost much of its popularity since the introduction of novocain. Although less toxic than cocaine, it is by no means free from danger unless used in very dilute solutions. According to Braun its action is weaker and is slower than that of cocaine or tropacocaine when introduced around nerve trunks, but quite as powerful when it is employed by intraneural injection. Since it diffuses much less readily than does cocaine, it is less advantageous for infiltration analgesia, and this is true even when adrenalin is present in the solution, as this addition rather accentuates the difference between β-eucaine and cocaine.

Poisoning by β-eucaine presents symptoms similar to those of overdosage by cocaine. Dose 0·097 grm. to 0·13 grm., if used in a 0·5 per cent. solution, but as much as 0·389 grm. may be used with a 0·1 per cent. It is never advisable to employ a solution higher than 2 per cent., nor is a greater strength needed.

STOVAINE.

Stovaine, $C_{14}H_{21}NO_2,HCl$, is the hydrochloride of a synthetic compound and is extensively used for producing spinal analgesia. It is also known as amylocaine hydrochloride, and occurs as a white crystalline powder, soluble in water, 1 in 14.

STOVAINE SOLUTIONS FOR INTRADURAL INJECTION.

A 5 per cent., weight in weight, solution of stovaine has the same osmotic pressure as the cerebro-spinal fluid, but since it is desirable to localise the action of the stovaine injected into the canal to some particular region of the spinal cord, some other substance must be added to the stovaine solution to increase its specific gravity.

BARKER'S STOVAINE-GLUCOSE SOLUTION.

· This is a solution containing 5 grms. of stovaine and 5 grms. of pure glucose in 90 grms. of distilled water. The solution has

a specific gravity of 1·024 as compared with 1·007, the specific gravity of cerebro-spinal fluid at 15.5° C. Glucose, while increasing the specific gravity of the stovaine solution, renders it to a small extent viscid, and thereby diminishes the diffusibility of the liquid.

Theoretically, dextrin is better than glucose, since it is a colloid substance possessing a negligible osmotic pressure, and therefore a very low diffusibility, while it serves to increase the specific gravity equally with glucose. It is convenient to keep the stovaine solution in sealed ampoules of hard glass each containing about 2 c.c. Since Barker's solution is a 5 per cent. one, each cubic centimetre will contain 5 centigrammes of stovaine.

Stovaine is an antiseptic salt, and requires only to be dissolved in a sterile glucose or dextrin solution. It is better to avoid boiling the stovaine. Stovaine is the hydrochloride of a base, and its solutions are easily decomposed if they are heated in glass beakers or stored in glass ampoules made of soft soda-glass containing excess of alkali, the base being precipitated from the solution in oily drops by the alkali which dissolves out of the glass.

It was first made by Fourneau. The employment of this drug for local and intradural analgesia has been introduced by Pouchet, Tuffier, and employed largely abroad, and has been used in this country by Barker. Stovaine is reputed to possess bactericidal powers, and according to Professor Pouchet, it is a cardio-excitant. Its use in **local analgesia** is less reliable than that of other drugs, but the experience which has been gained shows that it is satisfactory in spinal analgesia. It is stated to be less powerful than β-eucaine in local analgesia. It is used in 0·5 per cent. or 1 per cent. solutions for this purpose, the maximum dose being 0·13 grm., but is liable to produce **local sphacelation.** It has been extensively used for intradural injection, the maximum dose being 0·065 grm. to 0·07575 grm. Bier combines stovaine with adrenalin for spinal analgesia, but Barker deprecates this addition. As indicated above, Barker used a stovaine-glucose solution alone, and gave 0·04859 grm. as an average dose. Th. Jonnesco * of Bucharest states that, by adding small quantities of strychnine to the stovaine solution, the paralysant effect of the latter upon the medulla oblongata is counter-

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* *Deutsche medicin. Wochenschrift*, 1909, No. 49, p. 2155.

acted so that high intradural injections can be safely performed. These views are, however, not generally accepted in this country, and the high puncture is regarded as too dangerous to be recommended or practised.

NOVOCAIN.

Novocain, $C_{13}H_{20}N_2O_2,HCl$, is the hydrochloride of a synthetic base. It is a colourless crystalline salt, very soluble in water, 1 in 1. Solutions have been used for spinal as well as for infiltration analgesia, and for the nerve trunks (regional analgesia). A 5·07 per cent. solution (weight in weight) has the same osmotic pressure as the blood serum, hence it is necessary to add sodium chloride to the solutions in general use in order to make them isotonic.

The following solutions are isotonic, and they may·be sterilised by boiling without decomposition :

A. 0·25 per cent. Solution.

Novocain	0·25 grm.
Sodium Chloride	0·87 grm.
Distilled water sufficient to make . .	100 c.c.

B. 0·5 per cent. Solution.

Novocain	0·50 grm.
Sodium Chloride	0·82 grm.
Distilled water sufficient to make . .	100 c.c.

C. 2 per cent. Solution.

Novocain	2·0 grms.
Sodium Chloride	0·5 grm.
Distilled water sufficient to make . .	100 c.c.

PROPERTIES AND DOSE.

It is claimed for novocain that it has a low degree of toxicity, being one-seventh as dangerous as cocaine, and is non-irritant to the tissues. It is compatible with adrenalin, and is usually employed with it for local or regional analgesia. According to Braun, it is equivalent to cocaine in diffusive power and in intensity, and gives an equal duration of analgesia. It is a neutral compound and is not broken up by the alkaline

cerebro-spinal fluid as is the case to some small extent with stovaine. It is employed in 0·5 per cent., 1 per cent., and 2 per cent. for local, and in 5 per cent. solutions for spinal analgesia. Many workers regard 5 per cent. as unduly concentrated, and use 1 per cent. in the spinal canal (Hoffmann). In all cases the solution should contain adrenalin and be made isotonic by sodium chloride. The maximum dose is 0·75 grm. Paralysis of the external rectus muscle has followed the use of novocain in a few cases of lumbar puncture, as also when stovaine has been used. Muscular relaxation is less complete with novocain than with stovaine, and for this reason the former is a less suitable drug for spinal analgesia. Solutions of 0·4 per cent. may be employed for local infiltration, but 2 per cent. or even 3 per cent. is required for blocking the conduction of large nerve trunks (regional analgesia). Comparing novocain with stovaine, Professor Dixon states that the former is less toxic and less irritant, but weight for weight shows less marked analgesic properties. " Nevertheless," he adds, " the specific action of stovaine on nerve fibres is less than that of novocain, since stovaine destroys other tissues besides nerve fibres."

ALYPIN.

Alypin, $C_{16}H_{26}N_2O_2,HCl$, is a derivative of stovaine. It is a white, odourless, crystalline powder, very soluble in water, 1 in 1.

Solutions of alypin may be sterilised by boiling without impairing their analgesic action. Alypin is probably a dangerous drug and possesses few, if any, advantages over novocain or even cocaine. In ophthalmic surgery, Landolt points out that it acts as powerfully as cocaine, although more slowly, and is indicated in all operations on the eye when dilatation of the pupil is undesirable, since alypin has no mydriatic power. A 2 per cent. to 3 per cent. solution is used for this purpose. When injected, 3 to 6 c.c. of a 1 per cent. sterilised solution of alypin may be used. In dental practice, 1 to 2 c.c. of a 1 per cent. to 2 per cent. solution, with the addition of 2 drops of an adrenalin (1 in 1,000) solution to each c.c., is said to produce insensitiveness.

TROPACOCAINE.

Tropacocaine, $C_{15}H_{19}NO_2$, is an alkaloid which occurs in small quantities in Java coca leaves. It can also be prepared syn-

thetically. The hydrochloride of the alkaloid is a crystalline substance freely soluble in water. Aqueous solutions of the hydrochloride keep well, and they may be boiled without fear of decomposition. It has been used largely in spinal analgesia, the usual dose being 0·08 grm. (1·25 grains). It is said to cause few after-effects ; but some observers have reported sequelæ similar to those which have followed the use of stovaine and novocain. It is difficult to arrive at conclusions upon this point, as it is too often the custom to condone the occurrence of undesirable after-effects, and to ascribe them to errors of technique. Tropacocaine has been used in dental surgery.

ADRENALIN.

Adrenalin, $C_9H_{13}NO_3$, is the specific hormone of the suprarenal gland. It is prepared chiefly from the suprarenal glands of the sheep or of other animals. A synthetic product known as suprarenin differs from the natural substance in possessing no action upon polarised light, the latter being lævo-rotary. Suprarenin is believed to be therapeutically identical with adrenalin, it keeps well and possesses constancy of action. The British Pharmacopœia recognises only the natural substance. Adrenalin occurs as a light brown or nearly white minutely crystalline powder, only slightly soluble in water, but readily dissolved in the presence of acids, with which it combines to form salts.

Adrenalin in the solid form will keep indefinitely ; in solution it decomposes very slowly and then turns *brown*. The solution turns *pink* with a very slight trace of NH_3, which it is liable to absorb from the atmosphere.

Adrenalin in **very** dilute solution can be boiled for a short time without fear of decomposition.

A large number of preparations derived from the adrenals are obtainable, and are supplied under various names.

Liquor adrenalini hydrochloricus [B.P.] (1 in 1,000) is made by dissolving adrenalin in normal saline solution, acidified with very dilute hydrochloric acid. It contains 0·5 per cent. of chloroform added as a preservative.

One part in 200,000 of adrenalin produces marked ischæmia, and no more than 1 mg. (about 15 drops of 1 in 1,000 solution)

should be used in the course of an infiltration. Usually less is needed, and when the larger quantity is employed, great dilution becomes necessary, or toxic symptoms, palpitation of the heart, precordial oppression, and respiratory distress rapidly supervene.

Its **physiological action** is to contract the walls of the blood-vessels and capillaries. It is a greyish-white powder, slightly soluble in water, readily so in weak acids. It has no intrinsic analgesic effect, but when added to true analgesics it increases their effect. Even minute doses such as those employed by dentists are said to cause unpleasant effects, *e.g.* giddiness, fainting, and collapse. The synthetic product is stated to be less toxic than that prepared from the gland ; it is, moreover, of definite strength, and so gives more precise reactions.

QUININE AND UREA HYDROCHLORIDE.

The compound is $C_{20}H_{24}N_2O_2$ 2HCl . $CO(NH_2)_25H_2O$.

It is made by adding urea to a solution of quinine in HCl, filtering and crystallising. The crystals are soluble in their own weight of water.

Solutions containing 0·25 to 1·0 per cent. of the salt are used and analgesia is produced in from ten to thirty minutes, and may last for four or five days. The solution is infiltrated subcutaneously over the area to be rendered analgesic. Sloughing may follow its use.

The compound is non-toxic, and its solutions can be sterilised by boiling.

The main use of this preparation is to prevent reactionary pain coming on during the first few days consecutive to an operation. It possesses the objectionable property of producing a hard œdematous condition in the tissues infiltrated with it which persists for a considerable time after the injection, even for days or weeks.

METHODS OF EMPLOYMENT OF ANALGESICS.

Cocaine is used in the following ways :
1. Instillation into the eye.
2. Painting over mucous surfaces.

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3. Subcutaneous injections.
4. Infiltration (Schleich and Reclus' methods).
5. Spinal analgesia.
6. Neural or regional analgesia.

Whatever method be adopted, it should be remembered that a **dose** of 0·065 grm. will in a large number of persons produce unpleasant if not dangerous symptoms ; half this is a safer dose, though even half may in many people give rise to trouble.

1. In **ophthalmic practice** a few drops of a 4 per cent. solution are instilled into the conjunctiva ; this is repeated two or three times at brief intervals, and then five to ten minutes are allowed to elapse before operating. If the manipulation takes long, it will be necessary to repeat the process from time to time. Another and useful method of administration suitable for eye work is the placing of an easily soluble cocaine tablet in the oculofacial fold of the conjunctiva.

2. **For cutaneous and mucous surfaces.**—As a paint, it is of little use over the cutaneous surfaces as it is not absorbed. When employed for mucous surfaces, especially if there be any possibility that some of the solution may be swallowed, a dilution of 5 per cent. should be adopted. In laryngoscopic and rhinological examinations some recommend a 20 per cent. solution, painting the nasopharynx with it. When strong solutions are employed, great care must be taken to mop away all excess. Cocaine appears to be especially dangerous in the urethra, and should not be used in this situation.

Cocaine is also employed as a spray in an atomiser, a 4 per cent. solution being used.

In rhinological examinations, a dossil of wool soaked in a 5 per cent. solution is placed in the nares until sensation is lost.

3. **Hypodermic injection.**—Most marked effects, both local and constitutional, follow the use of cocaine when injected hypodermically. Employed in this way, its action is more rapid and more persistent than when applied as a paint or an ointment. Formerly a 10 per cent. solution was employed, and from 2 to 5 minims injected at the site of operation. As the effect may pass off before the operation has been completed, it was often necessary to inject a second or third dose. However, great care must be taken to avoid the injection entering a vein, since it is probable that many of the deaths following the use of cocaine have resulted from this accident. From

five to ten minutes must be allowed to elapse after injection before an incison is made. At the present time this plan of using cocaine is seldom adopted, and even when the infiltration method is employed, cocaine is often replaced by novocain or β-eucaine.

Dose.—When highly diluted solutions of cocaine are employed for infiltration, 0·065 to 0·097 grm. in a 1 per cent. solution is stated by Reclus to be a safe limit, and double this dose when $\frac{1}{2}$ per cent. solution is employed. However, this is a large dose and is seldom now employed. The addition of adrenalin is said to lessen the danger.

If cocaine is employed at all, the dose must be kept small and the concentration low. In dental surgery a number of fatal cases have been reported due to the incautious injection of cocaine into the gums by unqualified persons who appeared entirely ignorant of the dangerous character of the drug they were injecting.

When cocaine is used by the infiltration method as devised by Schleich, one or other of the following solutions is employed :

			No. 1.	No. 2.	No. 3.
Cocaine Hydrochlor.	.	.	0·2	0·1	0·01
Morphin. Hydrochl.	.	.	0·025	0·025	0·005
Sodium Chlorid. .	.	.	0·2	0·2	0·2
Aq. destill. sterilisat. ad.		.	100·0	100·0	100·0

These solutions are employed according as a deep, medium, or evanescent analgesia is desired.

INFILTRATION METHODS.

Schleich * of Berlin, Reclus † of Paris, and Oberst of Halle, impressed by the danger of using concentrated solutions of analgesics, have practised methods of local analgesia by the endermic and hypodermic injections of greatly diluted solutions of various analgesic substances. Drs. Braun and Heinz have systematised and simplified Schleich's procedure, and in

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* " Schmerzlose Operationen," Berlin, 1899. In this exhaustive work all Schleich's earlier work is focussed.

† *Rev. de Chirurgie*, p. 158, Paris, 1899. See also " La Cocaine en Chirurgie," Paris, 1895.

the following account of the infiltration method their directions are mainly followed.

The addition of morphine is valueless, and that drug should be omitted.

Before the use of novocain with adrenalin became popular, Braun adopted a solution composed of β-eucaine one part in a thousand of saline solution (sodium chloride eight parts) by weight. The β-eucaine is not decomposed by boiling, and so can be completely sterilised.

Technique of the endermic method (Schleich). — The syringe is constructed to hold 10 c.c. (see fig. 85). The piston must be absolutely true, and all the junctions must fit accurately, otherwise the .resistance offered by the tissues injected causes the solution to leak back above the asbestos piston. Such dense tissues as those of the sole of the foot, the scalp and periosteum of bones are extremely difficult to pierce and infiltrate, hence some persons pierce the skin with a tenotome before using the needle.

FIG. 85.—Syringe for use in local analgesia.

Braun's syringes are made so that they can be readily taken to pieces, boiled, and put together again. The solutions and syringe having been carefully sterilised and the skin thoroughly cleansed, the needle is inserted *endermically* and some solution injected. The needle is held almost parallel to the surface and a little of the solution injected, then, pushing the needle farther in, more solution is injected until the needle is completely buried in the skin. Needles of various sizes and angled hubs are needed. The first puncture should be made with a fine

sharp needle, as this gives least pain. The wheal resulting is again injected at its periphery, and this is injected in like manner until a linear zone of skin is rendered œdematous by the fluid introduced. Subsequent injections are made hypodermically, each one being firstly into the wheal, subsequently deeply into the subdermic structures. When the deeper structures are to be operated upon these also are injected. It is advisable to wait for some minutes, usually about twenty, between the time of injection and the performance of the operation. When the structures are cut, much of the œdema fluid flows away, but the tissues remain analgesic for about twenty minutes. Repeated injections are made as the operation is in progress. Large quantities of the solution may be employed. It is usual to scheme the line of injections in such a way that all skin areas which are to be cut are made analgesic. The nerves supplying them, and the deeper structures also, are rendered incapable of transmitting painful stimuli by injections made into the tissues surrounding them.

TISSUE INFILTRATION : BRAUN'S METHOD.

This method is the one which is now generally employed and is the most satisfactory.

The skin is first thoroughly cleansed and then the solution, syringe, and needles are sterilised in plain water or saline, since soda destroys the analgesic effect. A 0·5 per cent. novocain and adrenalin solution is employed.* A fine hollow needle is fixed to the syringe (fig. 85), and introduced into the deep tissues, care being taken to avoid the proximity of blood-vessels. As the needle is slowly withdrawn the solution is injected so that the subcutaneous tissues are the last to become permeated. If the whole area cannot be reached by deviating the direction of the needle, fresh punctures are made in the required direction, but always within the area already rendered analgesic. It will be found that for practically all areas a scheme of intersecting

* The solutions have been mentioned above (pp. 464, 467). Braun points out that when large quantities are to be infiltrated a dilute solution is advisable. The quantity of adrenalin introduced is important, as an excess leads to serious damage to the tissues infiltrated. One milligramme may be added to 200 c.c. of a 0·5 per cent. novocain solution, to 100 c.c. of a 1 per cent. solution, to 50 c.c. of a 2 per cent. solution, and to 25 c.c. of a 4 per cent. solution.

lines can be made which will intercept the nerves running from
the area to the centripetal nerve trunks. It may be necessary
or advisable to inject deeply beneath the growth or area to be
operated upon, but this is not always required, nor is it possible
if large blood-vessels traverse the region to be infiltrated. The
diffusion of the solution, although not great, will assist in isola-
ting deeply the operation site. It is wise to infiltrate wide of
the intended line of incisions, since it is not possible to anticipate
all the eventualities of an operation until it has been commenced.
The solution used should be freshly prepared and should be
isotonic with the tissue fluids. Hence the solutions of novocain
or other analgesic are made isotonic by the addition of sodium
chloride. Both in Reclus' and Braun's methods the endermic
system of Schleich is replaced by subdermic injection, and the
area infiltrated is controlled by the character of the operation
to be performed. When a long incision has to be made, the
anæsthetist commences with an endermic injection; a wheal is
thus formed, and subsequent injections are made in either
direction, but into the wheal, *i.e.* into the anæsthetised area.
Subsequently subdermic injections can be made through the
insensitive skin area. In most parts of the body such as the
scalp, the sensory nerve trunks of the skin and fasciæ run in
the subcutaneous connective tissue, and so large areas of the
contiguous structures of the surface of the body have no
connexion with subfascial tissue, and when this is the case
the skin and subjacent layers can be rendered insensitive by
a ring of injections around the site of the proposed operation.
These injections cut off the nerves which would normally convey
sensory impressions. Thus the injections from four or six
punctures may be schemed in such a manner as to enclose a
rhombus or square, and so will isolate quite an extensive surface
and allow of painless operation. Dense structures like the scalp
require care or the injecting needles will be snapped off. In-
jections into the mucous membrane and submucosa do not cause
persisting wheals.

The skin, periosteum, and bones of the skull are supplied
by nerves running in the subcutaneous tissue. When the nerve-
supply is derived wholly or in part from below, systematic
infiltration of the layers must be practised. The pleura and
peritoneum do not require infiltration, their nerve-supply being
derived respectively from subpleural and subperitoneal tis-

sues. The periosteum derives its nerve-supply from superjacent tissues, not from the bone, so that an attempt to obtain sub-periosteal injection need never be made. It is important to keep the point of the needle constantly moving so as to prevent injection into some one structure, e.g. a vein, and the anæsthetist must train his hand to feel the nature of the structure the needle is piercing, whether it grasps the needle or permits of easy movement in any direction. It is impossible in these pages to do more than indicate the rationale in some of the commoner surgical procedures. The anatomy of the part, and especially the distribution of the nerves supplying the area to be infiltrated, control the precise lines of injection, since, besides infiltrating the tissues of the area involved, it is essential to inject the points of exit of the sensory nerves innervating the site of operation. A few drachms of solution usually analgese an incision of three or four inches and produce a swelling over the injected area, which, however, gradually subsides. Although fat, muscles, and fasciæ can be injected through the skin, it is always better, when working in the line of important vessels or highly vascular structures, to inject the deeper layers as they are exposed in the course of the dissection. Merely bathing tissues has no effect ; the fluid must enter into their meshes to anæsthetise them. The time taken to produce an analgesic state varies with the tissue and the strength of the solution employed ; it may be fixed at from ten minutes to half an hour, and it is easy to test the sensation. However, such testing should be undertaken out of sight of the patient, and the result judged rather by watching his eye than interrogating him as to whether he can feel anything. Few answers so obtained are of any value, since tactile sense often persists for some time after analgesia has been produced.

Choice of Operations.

Although Professor Braun * indicates the possibility of per-forming operations upon practically every region of the body, it is not usual in this country to adventure with the use of

* For full particulars of Professor Braun's elaborate procedures in the use of local analgesia, the reader is referred to his work " Lokalanæsthesie," Dritte Auflage, J. A. Marth, Leipzig, 1913. An English edition, trans-lated and edited by Dr. Percy Shields, A.C.S., has been issued by Messrs. Kimpton, and much assistance has been obtained from these books.

analgesia upon those operations which involve difficult and deep injections into the foramina of the skull, or call for deep dissections.

Operations upon digits and toes, circumcision, Thiersch's skin-grafting, simple hernias, hydroceles, thyroidectomies, removal of circumscribed growths, sebaceous or dermoid cysts, fatty or fibrous tumours, warts, moles, etc., are commonly considered appropriate cases for local analgesia. When regional methods are adopted the range of operation is extended, thus resection of ribs for empyema, removal of gangrenous extremities, resection of varicose veins, excision of ganglia, and so on, can be readily performed by the aid of this method. The danger of injecting in the region of septic areas, and the inadvisability of trusting to local methods when it is impossible to foretell the limits of the operation, must be kept in mind in making the choice between local and general anæsthesia. Nor must it be forgotten that nervous, neurasthenic and highly strung patients suffer from psychic shock when they are conscious, so that such persons and children are not as a rule suitable for local methods. Some authorities, recognising this, advocate the employment of a mixed method. They either use the preliminary injections of scopolamorphine and atropine, or they associate a light narcosis such as that of nitrous oxide and oxygen with these drugs and local infiltration (see Chapter VIII.).

REGIONAL (CONDUCTION) ANALGESIA.

When it is sought to render any given area analgesic, the nerve trunks which supply it can be blocked by deep injections of novocain or other analgesics.* It is, however, neither necessary nor expedient to puncture the nerve sheath. What is aimed at is to inject the perineural tissues at a point where the nerve can be conveniently localised. The injection can be made practically painless by injecting a few drops as the needle pierces the superficial structures, or a preliminary endermic injection may be made, and the needle to be used for the deep injection can be introduced into the wheal so produced. In a few minutes

* A 1 per cent. or 2 per cent. novocain with sodium chloride answers well ; 5 drops of 1 in 1000 solution of adrenalin should be added to each 20 c.c. at the time of use—a 1 per cent. solution of novocain is used for infiltration, and a 2 per cent. solution for conduction analgesia.

the area controlled by the nerves involved can be tested. It should be borne in mind that some tactile sense persists after response to pain is lost. Ten to twenty minutes is the usual time taken to block a nerve trunk, but in the case of deep-seated nerves a longer time may have to elapse, and if the tissues round it are very loose a second injection may be called for. In making deep injections care must be taken to avoid puncturing blood-vessels. Whenever possible the nerve should be sought where no important vessel is in its immediate vicinity. The nature of the structures to be dealt with and their nerve-supply must be carefully studied. Copious injections should be avoided until the operator has satisfied himself that his line of injection is correct and the required depth of tissue has been traversed.

As the modern method of local analgesia is usually one involving local infiltration with injection into the perineural tissue, it is obviously impossible within the limits of this manual to give in full detail the requisite anatomical guides which must control the more complex procedures such as injecting the plexuses, the trunk nerves of the limbs, and the nerve trunks in the head and neck. It will, however, be useful to describe some operations to serve as types. Some of these are done by the " local," and some by the regional method. It may be pointed out that when a septic focus exists it is safe to use a regional method if the injections are made at a distance from the infected area. Although it is seldom advisable to perform extensive abdominal operations under regional analgesia, yet in such rare cases as those in which the method is forced upon the surgeon, it is useful to remember that the abdominal parietes are readily infiltrated, and that cutting the viscera does not give rise to pain unless traction is made upon them. Lennander,* whose careful work may be consulted, has shown this while he has demonstrated that the parietal peritoneum is, however, very sensitive.

Small subcutaneous growths such as sebaceous cysts, fatty tumours, papillomata, can be dealt with by circuminjection into the subcutaneous tissue surrounding the growth. The area which has to be made analgesic will vary with the operation, but it is better to inject too widely than too near the line of the incision. The actual line of incision can be injected, but this is

* *Deutsche Zeitschrift f. Chir.*, band lxxiii.

rarely necessary. In the case of large tumours an attempt should be made also to inject below them, in case all the innervating nerves have not been included in the area injected. In a case, for example, of an operation to be performed upon the chin, if the area isolated includes the mental foramen, circuminjection would fail, as a nerve-supply would be derived from the nerve passing through the foramen.

Tumours of the breast.—In the case of a benign growth the procedure is to lift the tumour from the underlying breast and surround the area by four lines injected from two or more punctures, introducing the needles in the required directions. The surrounding adjacent and subjacent tissues are also injected. In this way a complete breast can be ablated, although the procedure is not easy if the patient is fat.

Local analgesia is not to be recommended in cases of carcinoma mammæ.

Small non-malignant tumours occurring in other regions may be dealt with in a similar manner. When in the course of an operation deeper injections have to be made as successive layers are reached, it is necessary to allow time for the analgesic to act before cutting through the tissues.

Operations on the head and face.—The sensory nerves supplying the structures of the scalp and forehead traverse the fascia roughly in a line connecting the occipital protuberance with the eyebrows, passing in a circle round the head from below upwards, dividing as they ascend. They lie in the subcutaneous tissue and innervate the skin and periosteum, but not the muscles, so that flaps containing the latter can only be made after the muscles are also infiltrated. No special injections are needed for the bone and periosteum. The dura mater is insensitive except at the base of the skull, and the brain substance is wholly insensitive. Injection made around the area operated upon will cut off all but muscle nerves. As the blood-vessels run with the nerves, injections acting upon the latter will also render the area more or less ischæmic.

Local analgesic methods are best avoided when the scalp tissues are badly lacerated, unless it is possible to cleanse them from all dirt, and this is often impossible.

Although it is possible to remove tumours, *e.g.* sarcomata,

or clean out hæmatomata under local infiltration, it is not usually expedient unless the tumour is well defined and easily accessible. Bone-cutting operations for the exposure of the cerebellum are dangerous on account of the hammering on the chisel used to cut the bone. These procedures, if a general anæsthetic is not employed, call for the use of morphine with scopolamine, but such drugs react prejudicially upon the respiratory centre if much intracranial pressure is present.

Operations on the forehead and face call for blocking of one or all the branches of the **trifacial nerve** or of the **Gasserian ganglion.**

The ophthalmic nerve.—The injections made into the subcutaneous tissue transversely and above the eyebrows will block the peripheral branches ; the trunk of the nerve cannot be reached except by complicated and dangerous procedure.

Maxillary nerve.—**The infra-orbital branch** is reached by introducing a needle through the submucosa in the reflection between the upper lip and the alveolar process. The edge of bone is easily found and the foramen so reached. One c.c. of 2 per cent. novocain-adrenalin solution introduced into the canal effectually blocks the nerve and renders the following structures analgesic : The lower lids, the upper lip, the skin and mucous membrane of the alæ nasi, part of the skin and mucous membrane of the cheek, the anterior part of the alveolar border including the periosteum, the anterior wall of the maxilla, and the pulps of the central and lateral incisor teeth.

The superior, posterior, and median alveolar nerves.—These are best reached from within the mouth. The point of junction between the zygoma and the maxilla is felt for, and the needle introduced through the buccal mucous membrane to the posterior border of the upper jaw. Along this the injection is made. The area made insensitive includes the pulps of the molar and the premolar teeth and the mucous membrane of the antrum. The nerve-supply of the hard palate can be paralysed by peripheral injections.

As only the pulps of the teeth are affected by the above injections, other means, to be considered later, are requisite in dental operations.

The injection through the foramen rotundum and foramen

ovale and of the Gasserian ganglion involves delicate and difficult manipulation, being only adopted in major surgery.

The **maxillary nerve** can be reached in the *foramen rotundum*. The method adopted by Braun is as follows : A point is taken just behind the lower palpable angle of the malar bone, and the needle introduced inwards and upwards through the masseter to the maxillary tuberosity, and is forced along the surface of the bone. If the point engages against the wing of the sphenoid bone, the needle is slightly withdrawn and its direction altered until it passes into the pterygopalatine fossa at the depth of 5 to 6 cm., and the nerve is reached in the foramen. By withdrawing the needle slightly and injecting 5 c.c. of the novocain-adrenalin solution (1 per cent.) at the back of the maxilla, branches of the internal maxillary artery are constricted. Five c.c. of the solution are injected into the foramen. The sign of success is the radiating pain felt over the area of the nerve's distribution. A hæmatoma may be caused in the pterygo-palatine fossa, but the associated oculo-motor paralysis usually disappears when sensation returns.

The **mandibular nerve** is reached by the foramen ovale. Braun * gives the following method : A point is taken below the middle of the zygoma and the needle is introduced transversely. It will touch bone, the pterygoid process, at the depth of 4 or 5 cm. The point is now 1 cm. from the foramen ovale, and this distance is marked on the needle with a movable piece of cork. The needle is next withdrawn as far as the subcutaneous tissue, and is reintroduced a trifle more deeply at a slight angle. If successful, radiating pains will be felt by the patient. The nerve trunk is tough and is felt by the anæsthetist as he pushes in the needle. Five c.c. of a 1 to 2 per cent. novocain-adrenalin solution is required.

Injection into the Gasserian ganglion is a possible although difficult procedure, and one which requires considerable experience of the procedures employed in local analgesia. It is usually done under a general anæsthetic, as severe pain, vomiting, and vertigo commonly accompany the puncture. The usual route chosen is that of traversing the foramen ovale. Haertel sum-marised his method as follows.† The needle is introduced

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* *Op. cit.*, p. 225.

† This description is taken from Professor Georg Hirschel's "Textbook of Local Anæsthesia," translated by Dr. R. E. S. Krohn, p. 42.

into the cheek at the level of the alveolar border of the second upper molar tooth, a wheal being produced. The needle should be 10 cm. long, with a flat ground point and fitted with an aseptic movable scale such as a circle of sterilised cork. The needle is introduced, guided by the finger placed between the anterior border of the ascending ramus of the mandible and the maxillary tuberosity, round the buccinator muscle to the infra-temporal fossa. Viewed from the front the needle should point to the pupil of the eye of the same side when the patient looks straight forwards; viewed from the side, it should look towards the articular tubercle of the malar bone. Guided by the hard even structure of the infra-temporal surface, the needle strikes the foramen ovale, entering it from the anterior external longitudinal border. If the patient has not been anæsthetised, radiating pain is felt in the distribution of the mandibular nerve. The needle is then partly withdrawn, *i.e.* for a length of 1·5 cm., but not through the skin, and is then reintroduced into the foramen until radiating pains appear in the distribution of the maxillary nerve, and 1 c.c. novocain-adrenalin solution (2 per cent.) is injected.

Braun admits that the advisability of dealing with the Gasserian ganglion under local analgesia is open to question, as it involves some danger.

In all these procedures it is wise to have a skull at hand so as to identify the anatomy of the region. Fine needles of adequate length are required, and steady pressure rather than force is called for in introducing the needle. As deep regions are traversed and the most important structures are brought into the area of injection, absolute asepticity is necessary, a condition difficult of attainment when the needle is introduced through the mucous membrane of the mouth.

Every region of the head and face can be rendered analgesic by local or regional injections. The local infiltration plan is that of circuminjection around and wide of the area of operation. Each case has to be schemed according to the requirements obtaining, but the guiding principle is the same. This applies also to operations upon the mucous membrane of the nose, oral cavity, and post-nasal spaces. It may be useful to remind the reader of the **sensory distribution of the trigeminal nerve** to skin areas.

FIRST DIVISION.—The **lacrimal** nerve supplies the skin of

the lateral canthus; the **supra-orbital**, the upper eyelid, forehead and crown; the **supra-trochlear,** the skin of the median canthus.

SECOND DIVISION.—**Temporal branches** of the zygomatic supply the front of the temple, while the malar supply the malar region. The **infra-orbital nerve** innervates the alæ nasi, the lower lid, the anterior part of the cheek, and the upper eyelid.

THIRD DIVISION. — The **buccal nerve** supplies the angle of the mouth; the **auriculo-temporal** the anterior part of the auricle, the temple and cheek; while the **inferior dental nerve** innervates the mandible, and through its **mental branch** the chin.

As to the regions covered with mucous membrane, it should be noted that the first division, by its branches, supplies the upper and lower lids in part, the lacrimal sac, cornea and conjunctiva; the second division innervates the upper, and lower lids in part. The nasal cavity is supplied by both the first and third divisions, the ethmoidal cells, sphenoid sinus and frontal sinus by the first, and the antrum of Highmore by the second division.

Operations upon the tongue, if their area is quite localised, can be done, although usually inadequately, under local analgesia; if extensive, by regional blocking of the lingual, glosso-pharyngeal, and inferior dental nerves. The first is accessible by a similar injection to that adopted in anæsthetising the inferior dental nerve, by the inner side of which it descends to the base of the tongue (see below); but the glosso-pharyngeal is less easily reached, although Hirschel claims success following an injection made between the condyle of the mandible and the mastoid process.

Operations upon the jaws under local analgesia involve a complicated technique which cannot be considered in this place; the reader is referred to Braun's comprehensive manual for a clear presentation of the requisite steps.

ANALGESIA IN DENTAL SURGERY.

We may pass to the consideration of **operations upon the teeth.** For the adjustment of clamps and separators, the introduction of wedges, the application of ligatures for the rubber, for excavating, filling, trimming, or polishing deep cervical edges of cavities, the removal of tartar in pyorrhœa alveolaris,

the modelling of sensitive and irritable mucous membranes, cocaine as a paint of a 10 per cent. strength is used, or a spray of 2 to 4 per cent. according to the degree of sensibility manifested by the parts, may be adopted, or an equivalent of novocain-adrenalin solution. Cocaine or novocain is used before lancing and excising gum-tissue, and for the relief of pain after extraction, though it is usually inadequate to accomplish the latter. For anæsthetising pulps before extirpation cocaine or novocain is also useful.

Cocaine is unsatisfactory for tooth extractions, and should be avoided ; small doses are inadequate, and larger ones too frequently give rise to constitutional derangement which is often alarming. As a rule, a dose of 0·065 grm. is needed to anæsthetise sufficiently to permit of extraction, and ten minutes must be allowed to elapse before applying the forceps. The method of injecting is given below in describing the use of novocain, a drug which has replaced cocaine in dental practice.

Novocain and Adrenalin in Dental Surgery.

The two main uses of novocain are : for extraction of teeth (local or regional), and for prolonged painful filling (regional). Extraction may be attempted if a regional method is adopted when the tooth and environing tissues are septic, since a local infiltration is liable to carry infection into the deep tissues injected. Local infiltration is not in all cases successful, as some pain may be felt, and it is alleged the after-pain is increased. Nervous and hypersensitive persons, including children, are not good subjects for local infiltration in dental work.

An accurate knowledge of the innervation of the teeth and adjacent structures is necessary for satisfactory results.

Nerve-supply of the teeth in the upper jaw.—The **incisors** and canine teeth are supplied by the **anterior superior dental nerves** of their respective sides (maxillary nerve). The **molars** receive their nerve-supply from the **posterior superior dental nerves** (maxillary nerve) ; the premolars from the **anterior** and **middle superior dental nerves** (maxillary nerve). The **molar region of the palate** is supplied by the **anterior palatine nerve ;** the anterior part, *i.e.* the incisor and canine area, by the **naso-palatine nerve.**

The nerve-supply of the mandibular teeth.—The **inferior**

dental nerves supply all the teeth of the lower jaw. The nerves of opposite sides anastomose in the region of the central incisors, so that, if these teeth have to be rendered insensitive, the nerves on both sides must be blocked. The mental branch of the inferior dental nerve passes through the mental foramen and supplies the anterior labial surface of the mandible, the mucosa, and lower lip, and so has to be reckoned with if submucous injections are made about the anterior teeth. The mucous membrane in the molar region receives sensory fibres from the buccinator nerve (third division). The lingual aspect of the mandible is supplied by the inferior dental nerve, but fibres from the lingual branch are also involved. In practice, the lingual branch, wholly or in part, is usually intercepted by the solution introduced to block· the inferior dental nerve.

<center>TECHNIQUE.</center>

Two methods are open for adoption : (1) local injection, which is the one most usually employed for single teeth ; and (2) regional injection, wherein one of the trunks of the nerves supplying the teeth is blocked at the point where the nerve enters the bony canals of the maxillæ or mandible.

1. **Submucous Injection.***—The importance of cleansing the area of operation cannot be insisted upon too strongly. To this end are necessary a preliminary scaling of the teeth, washing the mouth with warm carbolic solution, and careful sterilisation of the hands of the operator, of the syringe, and of the solutions. An additional safeguard is painting the area of operation with solution of iodine or spirit. One of the older forms of syringe is the all-metal one of the " Record " type, with an accurately fitting asbestos piston and fine needles, which should be kept in alcohol. Various hubs are necessary to carry these needles. A glass syringe with an accurately fitting all-metal piston should be used. This should be kept wholly immersed in a solution of one part glycerine and two parts spirit. All needles and needle-holders must be boiled before use. The holders screw

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* The technique given is in the main that of Mr. J. Leycester Dudley Buxton. See also useful papers by Dr. Pare : *Trans. Odontol. Soc. of Great Britain*, March 1907 ; *Brit. Med. Jour.*, May 18, 1907 ; *Trans. of the Liverpool and District Odontol. Soc.*, Nov. 1907.

on to the syringe. The needles most useful are those with a lead top, of No. 17 gauge, in sizes 1 inch, 1½ inches, and 3 inches. As the lead dissolves in glycerine, these needles cannot be kept in the glycerine-spirit solution.

For local injection the 1-inch needle, for regional on the inferior dental 1½-inch, and on the maxillary 3-inch needles are required. Long needles are more easily removed if they break, as the fracture usually takes place half an inch or so outside the tissues injected.

Ampoules * containing 1 c.c. of 2 per cent. novocain solution, *i.e.* novocain 0·021 grm., adrenalin 0·000081 grm., and sodium chloride, can be procured, as well as tablets. These last contain 0·021 grm. novocain and 0·000054 grm. of adrenalin borate. One tablet dissolved in 1 c.c. (17 minims) of sterilised distilled water, or, what is better, in normal saline solution, gives a 2 per cent. solution. One to three tablets may be used for a dental operation, but three are seldom required. The preliminaries must be carefully carried out, and ample time allowed for so doing, since haste generally leads to failure. The gum can be rendered insensitive by surrounding it with a dossil of cotton-wool soaked in 10 per cent. novocain solution. This is left applied for five minutes. When the gum is analgesic and somewhat blanched the injections can be made. The needle is inserted into the gum about one-eighth of an inch from its margin, the needle being held at an angle of 45° to the long axis of the tooth. The needle is pushed slowly, with as little pressure as possible. If ischæmia is produced, after-pain will follow, and probably necrobiosis. The first puncture should be made on the lingual aspect, and a few drops of the solution forced out, before the needle turned to an acute angle to the long axis of the tooth, is pushed down to the periosteum. This point attained, the remainder of the solution is injected as the needle is withdrawn. Some time must be allowed to elapse —half a minute—between each injection. The buccal injections are made similarly. By the use of angular attachments, the posterior teeth can be successfully approached. One to three punctures are required, according to the tooth, while in the case of solitary standing teeth, a ring of several punctures round the tooth may be necessary.

With regard to individual teeth of the upper jaw, in the case

* These must be made of soda-free glass, or the novocain is destroyed.

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of incisors, canines, and premolars, it is best to rely so far as is possible upon submucous injections. A modified conduction plan may be adopted for the molars, 1·5 c.c. being injected into the region of the maxillary tuberosity, while the roots of the teeth are surrounded by submucous injections. An alternative is injecting about the posterior palatine foramen. No attempt should be made to inject the anterior palatine foramina, as injections in this position cause very considerable pain. The teeth of the mandible may be dealt with either by submucous injections, these being made on the labial aspect and towards the apex in the case of the anterior teeth; or by blocking the inferior dental and lingual nerves. This last procedure is usually considered preferable in dealing with the premolars and molars. For buccal injections, 0·6 c.c. to 1 c.c. or even 2 c.c. of this solution in difficult cases may be used. When periostitis is present more of the injection will be necessary.

The objective sign of the drug's action presented by blanching of the tissues is more trustworthy than the patient's statements about his sensations. However, the blanching should be slight, or severe pain and damage to the tissues will ensue. Also there will be liability to adrenalin poisoning. Patients of over fifty are very intolerant of adrenalin.

It is unsafe to inject any tissues which are acutely inflamed or septic. Unless a conduction analgesia is adopted, multiple tooth extraction under local analgesia is undesirable.

When the injections have been made there will be some blanching due to the submucous injections, and the appearance of this is usually a sign that analgesia is present, provided of course that the deeper injections have effectually paresed the nerves of the underlying structures. Analgesia usually develops rapidly. There is always a liability to escape of the solution through fistulous openings and through the sockets of adjoining teeth, or into soft spongy gum. In these cases the deeper structures will retain their sensibility, and the extraction will be painful. Injections into spongy tissues are never satisfactory. In the case of teeth which are awkwardly placed, such as upper wisdom teeth, the best plan is to scheme the injections so that they are made in the line of the nerves supplying the teeth. The tissues of the gums and periosteum are very dense, and unless care is taken the slender needles will break. They are especially liable to do this if they are not

kept from bending, or are hurriedly pushed home. It will be found that when in one place a needle will hardly enter any distance, if it is slightly withdrawn without being entirely free from the gum, its direction of entry can be altered and a more easy way found. As a rule the final injection should find its way between the roots of the teeth rather than alongside of a root. Twenty minims of a 2 per cent. solution are usually sufficient to analgese a single tooth.

Two injections, one on the labial and one on the lingual aspects of the tooth, are usually sufficient. No attempt should be made to get beneath the periosteum, as stripping it off causes great after-pain, is liable to cause a septic socket and some necrosis. Injection must be made **slowly,** otherwise severe pain is caused, and much of the adrenalin enters the general circulation, inducing toxic effects, giddiness, malaise, and so on. Spongy tissues do not retain the injection, and so cannot be dealt with by local infiltration. Although angular attachments may facilitate injections in certain positions, they are extremely liable to cause snapping of the needle, and so need great care in their use.

This description applies in the main to both jaws, but the palatal injections into the maxilla require some elucidation. The needle is inserted behind the tooth to be rendered analgesic, and is advanced slowly parallel to the alveolar process into the vicinity of the apex of the root, at which point 0·125 c.c. or 0·25 c.c. is injected. In the deep layers of the anterior palatine area diffusion is rapid, and injection is easier and less painful than is the injection into the gum (Fischer *). Multiple punctures are usually unnecessary, as with a little care and by partly withdrawing the needle it can be made to enter in various directions and anæsthetise an extensive area. A long needle is requisite for this. If necessary, the syringe can be refilled, the needle remaining *in situ*.

In the case of the posterior mandibular teeth, including the premolars, the injection is best made in the neighbourhood of the gingival papilla and usually just below it, the needle being carried horizontally along the alveolar border, since in this situation the injection diffuses most readily.

2. **Injection into the mental fossa.**—The position of the mental foramen varies, and may be in any spot between the canine and the first permanent molar. The technique of injection is as

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* " Local Anæsthesia in Dentistry," p. 149.

follows : A No. 17 gauge 1½-inch needle is introduced into the sulcus half an inch below the gum margin of the canine, the syringe being held parallel to the masticating surface of the lower teeth. It enters soft tissues, and if carefully manipulated should cause no pain. It is now directed backwards in the sulcus for about a half to three-quarters of an inch, the bevel of the needle being towards the jaw. As the needle is slowly withdrawn, injections are made very gently. If the injections are made rapidly, adrenalin symptoms are prone to develop after two or three hours.

For lower molars Fischer gives the following directions : " The needle is inserted slightly below the cervical margin of the gingiva, in the centre of the tooth lying anteriorly to the tooth to be anæsthetised, advancing as in the maxilla, buccally and straight to the periosteum, gliding under it a little forward, but not farther than the centre of the tooth to be anæsthetised." 1 to 1·5 c.c. of the solution may be injected.

Conduction Analgesia.

It has been indicated above that, although submucous injections of novocain-adrenalin solution suffice for the extraction of anterior teeth, and circumduction injection, *i.e.* multiple injections around the tooth, for some posterior and lone-standing teeth, yet for the removal of several teeth and for prolonged dental operations, conductive or regional analgesia is requisite. This is easily obtained in the case of the lower jaws, but less so in dealing with the maxillary teeth.

The Mandibular Teeth.

The **inferior dental nerve** can be located behind the protecting process of bone, the lingula, as the nerve enters the foramen. Between the two ridges of bone on the anterior surface of the ascending ramus is a hollow groove, and the inner oblique line is the guide to the position of the nerve. The ramus of the mandible commences behind the third molar and ascends steeply. It rests upon the alveolar border and is bounded in front by two well-marked ridges, an anterior and external, or buccal, and the internal oblique line on the lingual aspect. Between these lies the retromolar fossa, and above this depression

is the retromolar triangle. The inferior dental foramen, guarded by the lingula, is placed half-way up the internal surface of the ascending ramus. These guiding structures can be readily identified on the skull, and when this has been done, the opening of the fossa can be found without difficulty in the living subject. The lingula can be felt with the finger. The lingual nerve passes in front of the inferior dental nerve, and is usually involved in the analgesia induced by injections made for the latter nerve.

The syringe, which is to be held as if it were a pen, is introduced from the opposite side of the mouth and should lie behind the canine of the opposite side, the needle being introduced along the internal surface of the ramus. The foramen is higher in the adult jaw than in the child's, and the needle's course must be altered accordingly. The point of introduction should be 1 cm. above the level of the masticating surface of the molar teeth. No attempt should be made to effect an intraneural injection lest the veins be damaged. If the perineural structures are infiltrated the nerve will become paresed. Children are not good subjects for this method, as results in their case are uncertain. A 1½-inch needle should be used, but never more than one inch of it should be introduced. The injection is made slowly as the needle is withdrawn. In the case of the incisors this injection will not be sufficient, as they receive an additional nerve-supply, and hence, as has been pointed out above, either· this must be dealt with by injections into the mental foramen, or a submucous injection made about the teeth in question ; unless care is taken, deglutition may be interfered with, much distress and alarm being caused.

The Maxillary Teeth.

Posterior dental nerves.—Conduction analgesia of the nerve supply to the upper teeth is less simple, for although the nerves can be located as they enter the hard palate, the anterior branches cannot be injected without causing considerable pain. The anterior superior dental nerves can be found in the infra-orbital foramen, which is situated ½ cm. below the lower edge of the orbit and vertically above the first premolar tooth. Not more than 1 c.c. of the 1 per cent. novocain-adrenalin solution should be injected around, and not into, the opening of the canal.

For **regional** analgesia of the **maxillary teeth** two injections are necessary : (1) for the **maxillary branches** of the second division of the trigeminal nerve, and (2) for the **posterior alveolar nerves.** (1) A 3-inch needle is used, and 2 c.c. of a 2 per cent. novocain-adrenalin solution. The syringe is held penwise, the needle being made to pierce the sulcus opposite the situation of the first molar at an angle of 45°. The needle is passed upwards, backwards, and inwards, until two inches of it are embedded. A few minims are slowly injected, and then, after a pause of twenty seconds, the needle is gently withdrawn, expelling solution as it leaves the tissues, and the sulcus is massaged with the index finger. (2) A 1½-inch needle is required and 0·5 c.c. of 2 per cent. solution. The needle is entered half an inch mesially to the situation of the third molar, and injections made slowly as the needle is withdrawn. Slight transient unilateral paresis of the superior constrictor muscle may follow this injection. These (1) and (2) injections suffice for the **three molars**.

The **Premolars** are dealt with by a submucous injection high up in the sulcus on the buccal side, combined with a regional injection of the **infra-orbital nerve,** about the outlet of the **infra-orbital canal.** The last-named can be palpated, and a 1½-inch needle passed up in the canine fossa.

As the upper incisors are frequently supplied by nerves running along the floor of the nares, it may be necessary to infiltrate the tissues high up in the sulcus below the nose in order to catch these nerves.

The subject of producing analgesia for the various conservative operations of dentistry does not fall within the limits of this book. The whole subject is carefully described in Professor Guido Fischer's elaborate treatise on "Local Anæsthesia in Dentistry," and the reader is referred to this work for detailed information.

Disadvantages and Dangers of Local Analgesia in Dentistry.

Whether after-pain consecutive to analgesia is more severe is doubtful. Some state that it is absent, but many assert that it is often severe and prolonged. It certainly varies greatly in individuals, so that it is unwise to assure the patient that none will occur. Tissues of low vitality often react badly

towards local injections, and these, with tissues which are inflamed or septic, are prone to slough and leave bared bone to exfoliate. No doubt rigid asepsis minimises the liability to such happenings, and many observers of great experience deny that they have met with these accidents. Nervous persons and children feel the strain of the somewhat prolonged programme requisite for local analgesia. Relatively large injections even of novocain may cause circulatory depression and faintness, partly due no doubt to the patient's apprehension, although he will blame the method for these discomforts. Injections through an area of septic tissue are liable to inoculate the healthy tissues and cause abscess. Some operators have found that the use of adrenalin produces localised necrobiosis, and it is well to remember that the synthetic suprarenin is less liable to lead to this unfortunate issue, especially if the dose is kept low. Generally it should be recognised that, provided the dilution of the analgesic is high, there is less danger of evil effects accruing. A case has been reported of erotic hallucination following the injection of novocain which only developed after the patient had left the dentist's house. This is a warning that even local analgesia should not be undertaken unless in the presence of a witness.

Safety of analgesics.—The behaviour of these drugs towards the tissues has been studied by Dr. Le Brocq.*

Toxicity.—Taking cocaine as 1, his results are : alypin, 1·25 ; nirvanine, 0·714 ; stovaine, 0·625 ; tropacocaine, 0·50 ; novocain, 0·490 ; β-eucaine lactate (benzamine), 0·414.

Irritant action on tissues.—Novocain least ; cocaine slight ; all the remaining drugs caused hyperæmia, dilatation of the vessels, and ultimately some sloughing. Stovaine is very prone to produce local sloughing, and so is seldom employed for local analgesia.

LOCAL ANALGESIA IN SURGICAL OPERATIONS.

It may be convenient to refer in this place to some surgical operations which can be easily done with the aid of local injections.

Operations on digits.—After sterilising the syringe and needles and the novocain-adrenalin solution (1 per cent.), the skin, having

* *Brit. Med. Jour.*, 1909, vol. i., p. 783.

been cleansed and painted with iodine, is pinched up on the dorsal aspect of the finger, and a fine needle stabbed in close to the bone. The solution is slowly injected while the needle is pushed in until its point is near the palmar or plantar aspect. During withdrawal more solution is injected, about 20 to 30 drops in all, according as the finger or toe is slender or thick. A similar injection is then made on the other side of the digit. In ten minutes, if no swelling appears about the root of the digit, the needle may be reintroduced through the former puncture, and more solution injected, but across the base of the digit. If the line of incision is other than that indicated, the injection must be varied to suit this requirement. When the hand or foot is to be operated upon, it is best to infiltrate over the nerve trunks supplying the regions and inject in the line of the nerves themselves. Some surgeons use a Martin's bandage or rubber cord to produce first venous engorgement, and ultimately hæmostasis, but this is seldom necessary if adrenalin is added to the solution. It is also stated that when the cord or bandage is used at the same time that adrenalin action exists, there is a danger of permanent injury to tissues and even of gangrene. If the finger or toe is the seat of septic infection, *e.g.* a whitlow, local infiltration must not be attempted, but recourse must be had to a conductive analgesia by a perineural injection of the trunks of nerves which supply the digit.

Circumcision.—The prepuce is stretched taut, and the needle inserted anteriorly on the dorsal aspect, being gradually pushed to behind the corona. The infiltration is carried on as the needle is advanced. The whole of the prepuce is then slowly infiltrated from the original injection area, and will rapidly grow œdematous. It is wise to wait for some minutes before incising, as the fluid escapes as soon as the loose tissues are opened. This procedure should not be pursued if inflammation or purulent infection exists, nor is it suitable for children. Sometimes a regional method is attempted. For operations to relieve **phimosis,** Braun suggests circuminjections made in the coronary furrow. The prepuce must be drawn over the glans and either held or fixed by a ligature; the ligature is removed as soon as analgesia is complete.

Amputation of the penis requires careful circuminjection and deep injections into the corpora cavernosa. A 0·5 per cent. strength of solution is sufficient, and 30 c.c. may be required.

Operations on the scrotum and testicles.—The nerve-supply of the scrotum and tunica vaginalis comes from the perinæum, the terminal branches of the pudic nerve, and the posterior femoral nerve. Branches of the ilio-inguinal and external spermatic nerves supply it above. Braun's method of blocking this area is : (1) inject by punctures on each side of the spermatic cord where it crosses the pubes, and by another laterally where the scrotal skin passes into that of the thigh. (2) The spermatic cord being lifted up, an injection is made beneath the cord. If the cord cannot be raised, the needle is inserted into the skin over the position of the cord and carried deeply until the point touches the pubes. From this puncture three injections are made in a radiating manner perpendicular and lateral to the symphysis. The scrotal skin is then rendered analgesic by circuminjection around the desired area. Varicoceles can be dealt with in the same manner, but adrenalin had better be withheld, since its effects mask the size of the veins.

Suprapubic cystotomy can be more or less satisfactorily performed by injecting the bladder, after cleansing it, with an analgesic solution, and then injecting the perivesical tissues, using long needles. One puncture is made just above the pubes, and the other nearly midway to the umbilicus. The abdominal walls can be injected also through these punctures.

Minor operations upon the labia can be readily done under local infiltration. More extensive operations on the vulva need regional as well as local injections.

Radical cure of hernia (*Inguinal*)—1. **Reducible.**—The internal abdominal ring is sought for and the needle introduced one inch or one and a half inches outside this. The line of incision will extend inward to the root of the penis and must be widely infiltrated, the fluid being forced just below the skin. Half to an ounce of solution will be required. The next injection is made in the region of the cord and through the aponeurosis of the external oblique muscle. It is best to hold the syringe as nearly parallel to the skin as possible, and to infiltrate the internal ring as thoroughly as can be, that is, the region about the neck of the sac. The external ring must then be carefully infiltrated. It is occasionally necessary to re-inject some of the tissues, layer by layer, as the dissection proceeds, so a syringe ready filled should be at hand. 2. **Irreducible hernia.** The first steps are the same as those for reducible

hernia, but the area of the injection may be wider. Care has to be taken in the deeper injections that the gut is not punctured. Injections are finally made under the hernial sac, after it has been drawn upwards first to the right and then to the left side. The posterior surface of the scrotum must be rendered analgesic by circuminjection: 100 to 150 c.c. of a 0·5 per cent. novocain-adrenalin solution will be sufficient. ·

Femoral hernia.—The muscles and tissues below the fascia are injected as in inguinal hernia, and this blocks the genito-crural nerve. Deep injections are made beneath the fascia external to the cord. Subcutaneous injections are required over the area of operation. Braun specifies four points: one, that required in inguinal hernia, three fingers' breadth from the spine of the ilium towards the median line; the second and third, on either side of the hernial swelling and at the ends of the requisite skin incision, that is parallel to Poupart's ligament; while the fourth is beneath the hernial sac.

Umbilical hernia.—Here the injections are made round the tumour, great care being taken that when the peritoneum is reached no puncture is made into any gut which may lie in the sac. It is impossible to infiltrate the neck of the sac before the operation is commenced unless the finger can be introduced into the ring, so that a second infiltration should always be made beneath the aponeurosis when that structure has been laid bare. This is especially needful in the case of a strangulated umbilical hernia.

Thyroidectomy.—It is only possible to render the skin and subcutaneous tissues analgesic, as the relations of the structures underlying the goitre render deep injections dangerous. The operation is made less painful, but not entirely freed from distress, especially during the time that the goitrous growth is being dislocated, so the patient should have this explained to him, otherwise the fear of worse pain in store may cause syncope. It should, however, be remembered that cases vary, and individuals differ in their perception of pain so that while some will say they suffer severely, others deny any real pain. A wide ring of injection is made round the growth and across the line of incision, an effort being made to infiltrate the muscles. The position of the adjacent vessels and other structures must be accurately in the mind of the anæsthetist during his injections. Dr. Crile prefers to use nitrous oxide and oxygen following

the scopolamorphine and atropine injection in association with local analgesia in cases of thyroidectomy (see p. 366).

OPERATIONS ON THE RIBS.

The region to be operated upon is infiltrated along the line of the proposed incision and wide of it. Subsequently an attempt is made, by the use of right-angled needle-hubs, to infiltrate the periosteum covering the ribs to be resected, by introducing the needle over the rib, and there infiltrating the deep tissues. The better plan, however, is to attempt a regional anæsthesia. If this is done the ribs involved are marked, and a needle is introduced at the upper surface of the highest, if possible to the outer side of the erector spinæ muscle of the affected side. The needle will be felt to impinge upon the rib, and it is then withdrawn slightly and directed downwards until it slips into the subcostal groove along which the nerve runs, and 3–5 c.c. injected. This area being thoroughly anæsthetised, a similar procedure is adopted for the lower ribs. It is best to render analgesic the intercostal nerve trunks of a couple of spaces wide of the region of the contemplated resection. Ultimately the skin and subcutaneous tissues in the line of the skin incision and an inch or so wide of it are infiltrated. Dr. Rood * suggests making the injection near the angle of the ribs in the following way. The patient lies on his back with his arm raised. The needle is introduced below the level of the rib and turned upwards until it just touches the lower edge of the rib ; it is then slightly withdrawn and pushed in until it just misses the lower edge, when it will enter the subcostal groove and can be pushed in for a quarter of an inch and the solution injected.

OPERATIONS ON THE ABDOMEN.

Except for minor procedures in which the parietes are alone involved, and for hernia and scrotal operations, local infiltration is not a satisfactory means of producing analgesia. Infiltration and conductive methods are of value when used with general anæsthesia as in Crile's anoci-association technique, but spinal anæsthesia either alone or supplemented by general anæsthesia gives the best results. The use of infiltration

* *Brit. Med. Jour.*, Dec. 21, 1912.

circuminjection and regional analgesia for hernia and scrotal operations has been described above. Rendering the parietes analgesic presents no difficulty, and is accomplished in the same way as in the case of operations on the skin and subjacent tissues already described. Although it is possible to use infiltration analgesia for operations upon the upper abdomen, the plan is unsatisfactory, as the position in which the body has to be placed causes pain or great discomfort, so that a general anæsthetic is called for. The combination of spinal with general anæsthesia is certainly better in abdominal surgery, *i.e.* below the umbilicus. Pelvic operations are best done by spinal or sacral anæsthesia when general anæsthesia is contra-indicated.

Lines of Nerves in Regional Analgesia.

The success of regional analgesia resolves itself into an exact knowledge of the position and distribution of the nerves of various areas likely to be involved in an operation, as well as the surface guides to the positions at which the nerve trunks can be found. The procedure of first infiltrating a region and then dissecting down upon a nerve trunk which is subsequently injected, is too complicated to be lightly undertaken.

Certain nerves can be located fairly easily and injected from the surface without dissection, and the more important of them are indicated below.

The Upper Limb.

In the case of the upper limb, the **musculo-spiral nerve** (Plates VI. and VII.B) perforates the external intermuscular septum running from behind forwards at a point joining the upper third with the middle third of a line between the insertion of the deltoid and the external condyle of the humerus (Rawling).

The **median nerve** (Plate VII.A) runs in front of the wrist to the ulnar side of the flexor carpi radialis beneath the tendon of the palmaris longus.

The **ulnar nerve** (Plate VII.A) is accessible in the forearm, as it lies in the hollow between the internal condyle and the olecranon process. At the wrist it is placed to the outer side of the tendon

PLATE VII.

A.

B.
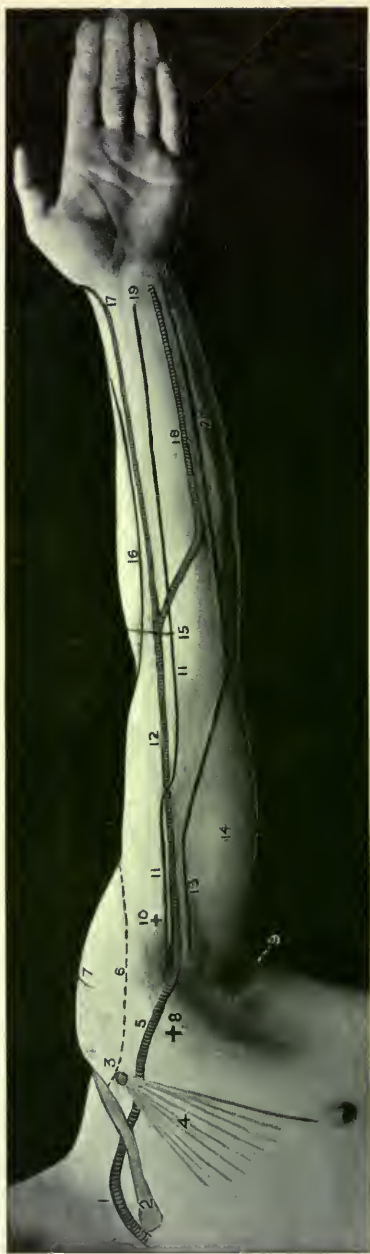
1. The acromion spine. 2. The acromion process. 3. The circumflex nerve and arteries. 4. The insertion of the deltoid.
5. The external condyle of the humerus. 6. The musculo-spiral nerve. 7. The posterior fold of the axilla. 8. The radius.

7. Circumflex ulnar nerve. 11. Median nerve in the arm. 13. Ulnar nerve in the arm. 16. Radial nerve. 19. Median
nerve in the forearm. 20. Ulnar nerve in the forearm.

PLATE VI.
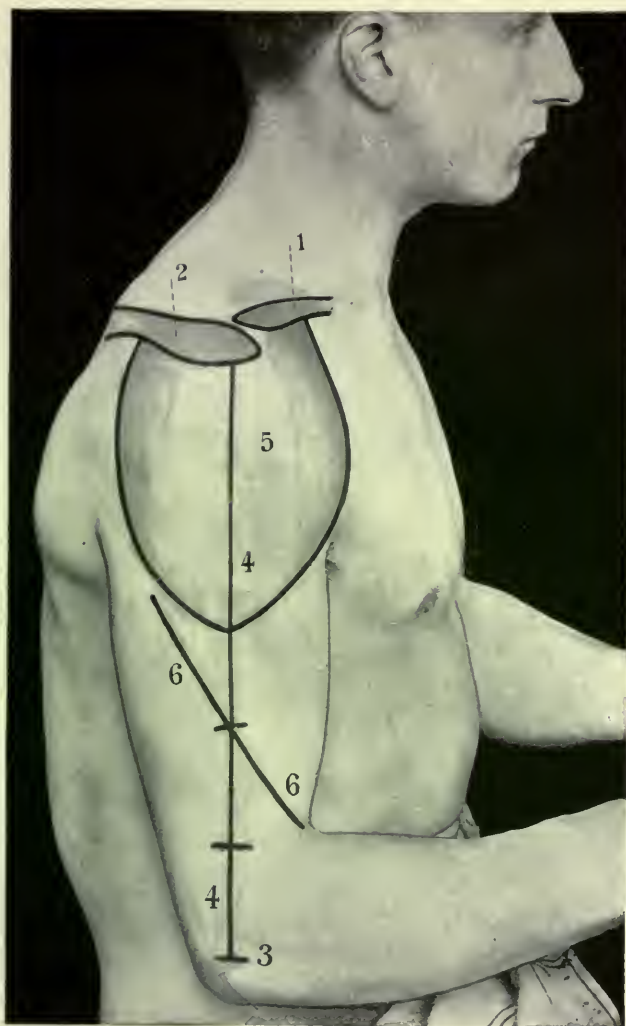
1. The clavicle.
2. The acromion process.
3. The external condyle of the humerus.
4, 4. Hamilton's line.
5. The deltoid muscle.
6, 6. The musculo-spiral nerve.

of the flexor carpi ulnaris. The needle is entered between the bone and the nerve, close to the former.

The **radial nerve** (Plate VII.A and B) is less easily found. It lies in the middle third of the forearm to the outer side of the radial artery, then passes under the tendon of the supinator longus to the outer side of the radius.

The **internal cutaneous nerve** can be blocked at the elbow at a point three-quarters of an inch internal to the biceps tendon.

The **musculo-cutaneous nerve** lies to the outer side of the biceps tendon. In both these cases the injection must be carried down to the deep fascia.

Operations on the arm and forearm—Injection about the brachial plexus.—Hirschel's method * is as follows : The patient lies on his back with the arm held upwards ; the position of the brachial artery is then localised with the left hand, while the syringe held in the right is placed so that the needle lies parallel to the arm, its point towards the axilla. The puncture into the skin is made over the vessels near the insertion of the latissimus dorsi muscle, and the solution (2 per cent. novocain-adrenalin) injected as the needle is advanced. After about 10 c.c. have been injected over the artery for a distance of 3 to 4 cm., the needle is partly withdrawn, the artery is held aside, and the needle is reintroduced more deeply and injections are made on each side of the vessel. These catch the ulnar and radial nerves, and an injection beneath the artery should block the musculo-spiral nerve. The needle is next pushed upwards towards the first rib as far as possible and under the pectoralis muscle, so as to block the musculo-cutaneous nerve. The circumflex nerve lies at the same level but below the artery. Ten c.c. are injected at each of the points named. The procedure is one of some difficulty, but wounds of the vessels have not been recorded ; although they are easily made, they can be usually prevented by constant injections as the needle is pushed onward. If successful the whole region of the arm, forearm, and hand becomes insensitive to pain. Kulenkampff reaches the plexus in the supra-clavicular area ; but his plan is no simpler than the one described, and does not produce so extensive a blocking of nerves.

Superficial operations on the arm, forearm, and hand can be done either by local infiltration or by blocking individual nerves.

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* "Textbook of Local Anæsthesia," p. 138.

The position of these and the points of accessibility are given above.

Amputations may be performed, when the tissues are not septic, by circuminjection of the area involved in the incision and deep infiltration; but in this case, as well as that of septic wounds, it is better to rely either upon blocking the brachial plexus or the nerves which innervate the areas involved. Local infiltration for amputation of the fingers is described above.

THE LOWER LIMB.

The **anterior crural nerve** (Plate VIII.B) passes under Poupart's ligament midway between the anterior superior iliac spine and the spine of the pubes, and lies half an inch outside the common femoral artery.

The **great sciatic nerve** (Plate VIII.A) lies in a line taken midway between the ischial tuberosity and the great trochanter, passing vertically downwards to the popliteal space. It divides at the junction of the lower and middle thirds of this line, and can be found as it emerges from the hamstring muscles. However, it is more convenient to block the smaller branches than the main nerve.

The **external popliteal** (peroneal) **nerve** (Plate VIII.A) follows the tendon of the biceps, passing round the anterior and external aspect of the leg an inch below the head of the fibula, where it divides. It can usually be felt as it winds round the bone. The needle has to be pushed down to the bone.

The **posterior and anterior tibial nerves** accompany the arteries of the same name (Plate VIII.A and B).

Operations on the thigh, leg, and foot.—Plexus analgesia is not successful in the case of the lower limb. In major operations spinal anæsthesia is preferable, and in the minor cases local infiltration can be adopted. There are objections to spinal anæsthesia in diabetes, so that the removal of a gangrenous foot or toe should be performed under regional analgesia.

Crile has suggested a dissecting operation to expose the sciatic nerve, and secures blocking by endoneural injection.

The **internal popliteal nerve** (tibial nerve) **and long saphenous nerve** are best blocked separately. The needle is introduced vertically in the middle line of the popliteal space to a depth of 0·5 to 1 cm., and 10 c.c. of 2 per cent. novocain-adrenalin

PLATE VIII.

A.

B.

12. Great sciatic nerve.
13. Internal popliteal nerve.
14. External popliteal nerve.
21. Posterior tibial artery and nerve.
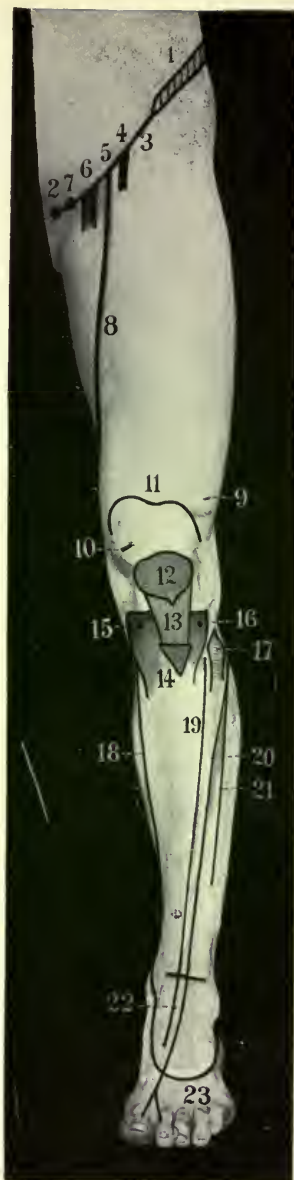
4. Anterior crural nerve.
20. Anterior tibial nerve.
21. Musculo-cutaneous nerve.
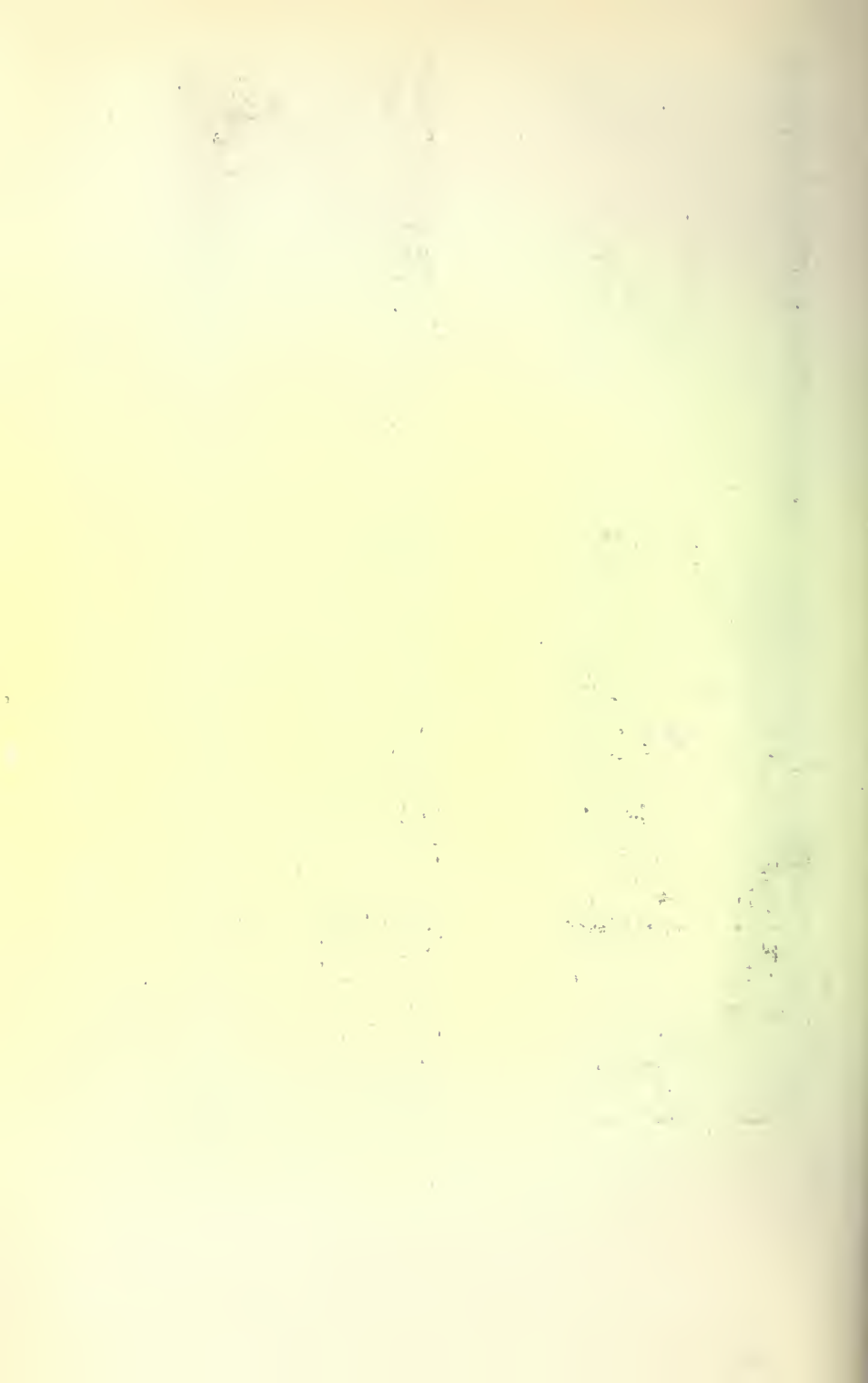
solution injected; this injection usually affects the short saphenous nerve as well as the internal popliteal. If introduced too deeply, the needle will reach the vessels.

The **external popliteal nerve** can be felt behind the head of the fibula and there injected.

The **long saphenous nerve** is blocked by a subcutaneous infiltration along a line below the knee-joint at the inner surface of the leg (Hirschel). These injections should render the leg and foot analgesic. The injections for amputation of the toes is done in a similar manner to that described above in the case of the fingers, regard being had to the directions in which the nerves which innervate the area are known to run.

After-effects of Local Analgesia.

Although these are negligible in the majority of cases, it must be remembered that some persons suffer more or less seriously from sequelæ.

Deaths have occurred following hypodermic injection in persons the subjects of status lymphaticus. Serious sepsis has also occurred from infected solutions or instruments.

Acute mania lasting for weeks has followed a hernia operation performed under local analgesia. Insomnia is not uncommon, and severe headache may occur. Mr. G. H. C. St. George Griffiths * states that reactionary hæmorrhage is common when adrenalin is used, and serous exudation may cause trouble. He also records back pain, pulmonary sequelæ with troublesome thirst and flatulence, and the frequent occurrence (30 per cent.) of mild jaundice.

SPINAL ANALGESIA.

Paravertebral, Parasacral, Spinal and Epidural Analgesia.

Corning's experimental work done in 1885 on the dog was the first attempt to produce analgesia by injecting drugs into the region of the spinal theca. In 1891 Quincke introduced the lumbar puncture, which Bier and Tuffier used as a means of

* *Lancet*, May 1, 1920, p. 960.

producing analgesia. The former tried the method upon himself. A. E. Barker developed the technique, publishing his results in 1907–9, and popularised the procedure in Great Britain. Epidural analgesia by sacral puncture was practised first by Cathelin, who employed this method in the treatment of neuralgias affecting the lower half of the trunk. The methods named above are divisible into three categories : (1) those which attempt to produce analgesia by injections acting upon the spinal nerves *after* they have left the dura (paravertebral or extradural); (2) those which produce analgesia by introducing drugs into the dura (intrathecal or intradural) ; and (3) those which cause loss of sensation in the areas innervated by the lower lumbar and sacral nerves by injecting into the subdural space below the termination of the theca spinalis, and so act upon the terminal nerves given off from the spinal segments (epidural). True spinal anæsthesia—that is, direct effect upon the structures of the spinal cord—probably only occurs through accident, the mechanism of spinal analgesia being, in fact, a regional analgesia in which the spinal nerve roots are affected. Cases have been recorded of spinal cord injury and spinal disease following injections, and these are probably the result of accidental injection into the cord and are preventable. How far the influence of the injection extends beyond the nerve roots, especially the sensory roots, and block the spinal cord itself it is impossible to decide, but it is probable that such an effect is negligible.

Tuffier regarded the paravertebral injections as safer than, and just as effective as, the intrathecal injections ; but it is doubtful whether the former method is sufficiently precise when carried out by methods at present available, and so it is not commonly attempted. The injected fluid is liable to spread, and so no very definite area of analgesia is obtained, and failures are frequent and apparently unavoidable. Parasacral injection is open to a similar criticism.

Paravertebral Analgesia. — The roots of the spinal nerves unite in the intervertebral foramina. The division into anterior and posterior branches occurs at once, hence the injections are made so as to block them at this point of division, since this will also block the communicating branch from the anterior division which links up with the sympathetic system.

Method.—The needle is introduced one and a half inches

from the middle line and directed upwards and inwards towards the intervertebral foramina. The average interval between the transverse processes in the dorsal region is about a quarter of an inch ; the midpoint of any space being about one inch vertically from the midpoint of the adjacent space. In the lumbar region, these measurements are half to three-quarters of an inch and one and a quarter inches.*

In the **dorsal region** the spinous processes do not offer a reliable guide to the position of the transverse processes, so that it is necessary to feel with the point of the needle for the intervertebral space. In the **lumbar portion** of the column, the lower border of the transverse process lies slightly below the level of the tip of the spinous process of the corresponding vertebra. The **cervical region** presents some difficulties, and, as Braun has pointed out, there is a very real danger of the injection entering the theca owing to accidental puncture of the dura by the needle. Such an accident may produce serious consequences. Kappis has shown that, even if this accident does not occur when an injection is made at the intervertebral foramen, the solution may penetrate the dura and reach the spinal canal. In the cervical region Kappis introduces the needle from the back, guiding it laterally along the spinous processes to the transverse processes and slightly beyond them. He uses a 1·5 per cent. novocain-adrenalin solution. Heidenhain injects from the side, the positions of the transverse processes being plainly marked before the injections are commenced. The region of and between the third and fifth vertebræ is thoroughly infiltrated, since at this spot the nerves lie close together. Paravertebral analgesia may be useful in exceptional cases of operations upon the neck or thorax, when other methods are inapplicable, but the difficulties and dangers of the procedure at present do not recommend it as a casual or routine method.

The instruments and drugs employed are the same as those required for intradural injection, and are described below.

Parasacral Analgesia.—The needle is introduced on the anterior aspect of the lower free margin of the sacrum, three-quarters of an inch from the middle line. Inspection of a skeleton will show that, if the needle is pushed straight upward and slightly

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* These measurements are those obtained by Dr. Allen. See " Local Anæsthesia," 1914, pp. 454 *et. seq*. Dr. Allen gives detailed descriptions of the methods of Paravertebral Analgesia.

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outwards, it will pass over the fourth, third, and second sacral foramina. To reach the first, the needle has to be slightly withdrawn and reintroduced with the point somewhat raised in order to clear the overhanging first sacral segment. It is then pressed in for about an inch, the distance between the first and second foramen. The interval between the second and third and that between the third and fourth is three-quarters of an inch (Allen).

Spinal analgesia consists in the injection *into* the subdural space of some agent which will act upon the nerve roots as they pass into or from the spinal cord. Their conduction is blocked, and so the area innervated by the nerves associated with the segment or segments affected becomes wholly insensitive to trauma. Whether the conveyance of every stimulus is blocked appears to be undecided, but the consensus of opinion seems to be that shock is to some extent abrogated by this procedure. The drugs most commonly employed in this country are stovaine, tropacocaine, and novocain (see pp. 460 *et seq.*). The technique varies in the practice of many surgeons, but that of the late Mr. A. E. Barker, with which most workers in this country agree, will be followed in the main in the appended description.*

The figures show the syringe and needles which are requisite, and the solutions recommended are given on p. 513.

The dose of the stovaine-glucose solution is 3 to 6 centigrammes, an average dose for the adult being 5 centigrammes. The postures assumed by the patient are accurately depicted in figs. 86 and 87, which are from photographs by Dr. E. Worrall, and are reproduced by Mr. Barker's permission from his paper dealing with the subject. Analgesia usually develops in from five to ten minutes. The symptoms are formication in the feet, disappearance of the cremasteric and patellar reflexes, followed by skin analgesia in the perinæum and lower limbs and gradually higher and higher up the body to the xiphisternal notch. The height reached depends upon the dose and upon the depression of the dorsal curve. Analgesia persists for from twenty minutes to as long as two hours in exceptional cases ; the dose is an important factor in determining the duration. Although some Continental surgeons employ adrenalin,

* See Mr. Barker's original papers, *Brit. Med. Jour.*, March 23, 1907, Feb. 1, 1908, Aug. 22, 1908, and March 16, 1909.

while others add strychnine to the injection, in this country
the general opinion of those who have enjoyed the widest ex-
perience is opposed to any such additions.* The· mechanism
by which the fluid injected traverses the cerebro-spinal fluid
is of great importance, as it is essential that the area of influence
of the analgesic shall be confined within safe limits. If this is
not done, there is danger of its effects trenching upon the medulla,
and interfering with the nerve controls over respiration and
circulation. Opinions differ as to this mechanism, and the
position of the patient is decided by the view adopted. Gwath-
mey, Morton, and others have recorded cases of complete anal-
gesia of the whole body, permitting operation even on the
maxillæ. These cases appear to have been injected with cocaine,
and that drug possesses a general as well as a local action. In-
deed, the evidence of such extreme practices as the high dorsal
and cervical puncture fails to carry conviction as regards their
safety.

Site of Puncture.—Careful dissections made of the cord and
its coverings indicate that there is least danger of doing damage
to the cord or the cauda equina when the region of the lumbar
spine is selected. In children the cord extends lower than in
adults. The best point of puncture is usually between the
spines of the third and fourth lumbar vertebræ ; some surgeons
advocate the interspace between the fourth and fifth, but this
position is often difficult to negotiate owing to the irregularity
of the spinous processes. Dr. Rood † prefers to inject between
the spines of the eleventh and twelfth dorsal vertebræ. He
states it is easier and does not increase the risk of damaging
the meninges.

Barker emphasised the importance of the injected fluid pos-
sessing certain properties. It must be aseptic ; it must produce
transient and not permanent effects ; its use should enable
the effects to be strictly localised to such nerve roots of the cord
as the operator desires to influence, thus ensuring the safety
of the medullary centres.

Two types are in use : one heavier than the cerebro-spinal
fluid : this is less diffusible, its movements being controlled

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* The addition of adrenalin is probably dangerous on account· of its
causing paralysis which persists even if it does not permanently injure
the cord.

† *Proc Roy. Soc. Med.*, 1919, vol. xii., Sec. " Anæsthetics," pp. 1–11.

by gravity for some minutes after injection ; and the light or diffusible solutions. In the first class the analgesic is dissolved in saline or water which has been thickened by the addition of dextrose, glucose, dextrin, or gum-arabic. In the second type the analgesic is dissolved in sterilised water, saline, or cerebro-spinal fluid. The analgesic agents most in use are stovaine (Barker), novocain, cocaine, tropacocaine, and alypin. Rood finds novocain, although giving perfect anæsthesia, does not produce satisfactory muscular relaxation. Cocaine, tropacocaine, and alypin are more dangerous drugs, and are less often used in this country.

Stovaine may be kept for fifteen minutes at 115° C. without damage. The injected fluid should have an osmotic tension equal to that of the blood serum (Barker). Such a solution containing stovaine is found in Barker's stovaine-glucose solution, and although, like all stovaine solutions, it is hæmolytic, yet the amount of the destruction of tissue cells must be very slight when only 5 centigrammes are injected. The question of the advisability of using a heavy or a light solution is an important one, and depends upon whether we accept the view that the passage of the injected fluid through the liquor spinalis is due to diffusion, oscillation, and movement of the liquor spinalis, or is controlled by gravity. Barker, in the paper cited above, describes some careful experiments *in vitro* which seem to warrant his statement that gravity can be made to be the main factor in the process. At all events, when a heavy more or less viscid iso-osmotic fluid is employed, the anæsthetist retains control of the amount of excursion of the injected fluid. With the body on the side or on the back, and the head raised on a pillow, the highest point in the curve of the spinal canal is the foramen magnum. The lowest is in the region of the fifth and sixth dorsal spines. The curve rises above to the third cervical vertebra, which is the highest point of the vertebral column proper, and below to the junction of the third and fourth lumbar vertebræ, the point of common election for puncture. From this spot downwards it falls to the level of the third sacral vertebra, where the dura ends. With these facts in mind, it will be recognised that by raising the trunk, as in the crouching posture shown in fig. 86, the injected fluid tends at once to gravitate downwards into the sacral sac, so that only the lower parts of the pelvis and the lower limbs become anal-

gesic. Conversely, if the patient is injected when lying on his side (fig. 87), or when prone, and is then turned into the supine position, the region of the mid-dorsal vertebræ is affected, and the analgesia ascends to the xiphisternal notch. When the buttocks are raised not more than an inch by a padded board under the sacrum, the fluid will ascend higher provided time is allowed for the action of gravity. The safety of the medulla depends, then, upon the head being kept high and bent somewhat forward in order to emphasise the cervical curve. Important as is this posture at the time of injection, wider experience of the method has shown that persistence in the raised head position may lead to an undesirable fall of blood-pressure. Rood, who has had a wide experience among patients of ages between a few hours and eighty years, allows the patient to be placed flat on his back a few minutes subsequently to the injection of heavy fluids, such as the dextrin or dextrose-stovaine solutions, as he believes that the drug is " fixed " five minutes after its injection. From this it would appear that the Trendelenburg position is a safe one after a sufficient time subsequent to the injection has elapsed to ensure fixation. Indeed, Rood states that even when light, that is diffusible, fluids are used, the semi-inversion position may be safely adopted. These statements must be accepted as the result of present knowledge, although it may be remembered that they are opposed to the experience of many of the workers who adopted spinal anæsthesia in its earlier days. How far individual cases may prove exceptions to the general rule it is impossible to decide.

Technique.—The syringe, needle, cannula, and stylet should be used only for spinal work ; they should be carefully washed in sterilised water immediately after use, especially if a glucose mixture has been employed, and should be carefully sterilised by boiling. It is essential that no soda is present during the process, or the analgesic power of the drug will be destroyed. It is best to keep a small steriliser for this purpose, and for this alone.

The solution in ampoules holding about 2 c.c. is already sterilised ; but if a solution of stovaine and glucose has been freshly prepared, it must be subjected to a temperature of 212° F. for fifteen minutes.

The skin of the patient's back must be carefully cleansed with soap and water, subsequently wiped over with spirit. If

painted with iodine, water must not have been previously used. At the moment of puncture no antiseptic must be on the skin, as its introduction into the theca will cause irritation. The patient need not pass through the rigid stage of fasting prescribed before general anæsthesia unless it is proposed to supplement the stovainisation by using a general anæsthetic, a plan which has of late years become more and more usual.
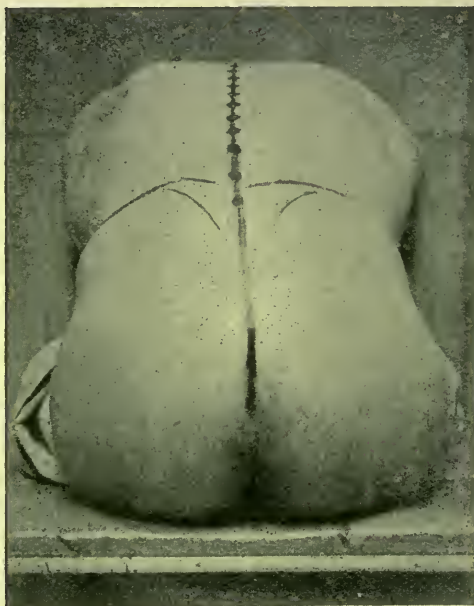
Fig. 86.—The patient sitting on the table with his buttocks near the edge, his body bent forwards to bring the spinal curve into prominence. From a photograph by Dr. Worrall.

Some sickness is not very uncommon after spinal puncture and so it is as well to let the patient have his meal two or three hours before the operation, and restrict it to easily digested liquids. Some persons suggest giving alcohol just before the puncture, but this is usually quite unnecessary, and is obviously undesirable.

A preliminary hypodermic injection of scopolamine, morphine, and atropine may be given to adults, but had better be withheld from children. This is now admitted to be useful since

the danger of spinal analgesia is largely a circulatory one. Mr. Percival Cole suggests blocking the ears with cotton-wool and keeping the eyes covered with a bandage. It should be remembered that many persons are frightened and rendered suspicious if their eyes are covered, so that a screen placed across the body is often to be preferred to an eye bandage. Again, it is a practice with many surgeons abroad to spray the skin with ethyl chloride before puncture, or to infiltrate it with novocain or β-eucaine lactate. Save in exceptional cases, however, it is
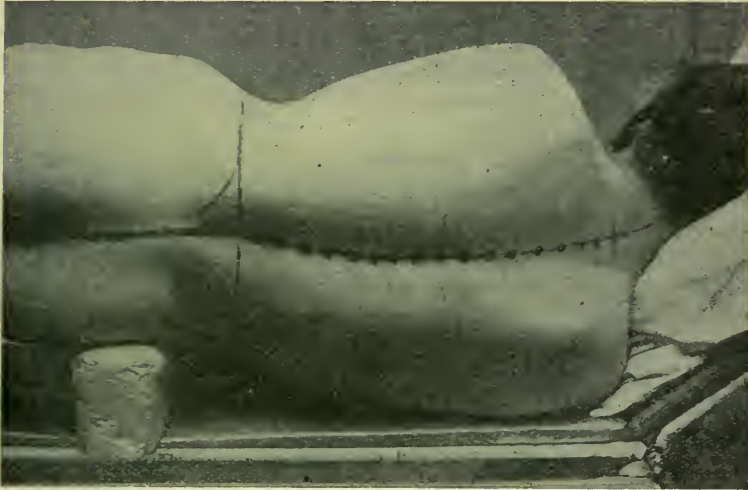
FIG. 87.—The patient lying on his side in the correct position for puncture, except that the upward bent thighs are not illustrated. From a photograph by Dr. Worrall.

best to avoid elaborating the procedure and fussing the patient, who, if he has never undergone the process, is naturally somewhat nervous.

Posture.—If the **crouching posture** has been selected (fig. 86), the patient sits upon the table with his buttocks towards the operator, his feet resting upon a chair, and his body bent forwards and downwards, his hands resting upon his knees.

The lumbar spines should be made prominent, and this will be effected by the forward arching of the body. If left to himself the patient will keep his back straight and incline his

axial line at an acute angle to the table. He must be made to bow his back out to the requisite degree.

In the **lateral position,** which, although less easy for the operator, gives a higher and more prolonged analgesia, the lower shoulder is carried forward, the head raised and flexed on the chest, and the thighs strongly flexed upon the abdomen. The whole trunk is made to incline backwards, so that the side which is uppermost is in a plane slightly posterior to the lower—that is, is a trifle nearer the operator, who sits upon a stool facing the patient's back. In this position the curves of the spinal column should be readily traced, and the lumbar spines prominent. In stout persons and in muscular men the spines are not so easily made out, but by forcible flexion of the head and lower extremities they can usually be felt on deep pressure.

In the figure the pelvis is raised upon a block, but this degree of elevation is seldom needed unless the pelvis is very narrow or high range of analgesia is sought. The insertion of a one-inch board covered with mackintosh and a sterilised towel usually suffices, but the degree of elevation must be judged of in each case by the inspection of the pelvis and consideration of the necessities of the operation. As a rule, it is best to restrict the method to operations upon the lower limbs, pelvis, and lower half of the abdomen. In women with a broad pelvis nothing is required under the hip.

The line connecting the highest point (*i.e.* in the erect posture) of the iliac crests will pass over the superior aspect of the spine of the fourth lumbar vertebra, so that the point of election for puncture in this region will be immediately above this, between the spines of the third and fourth lumbar vertebræ. Although some authorities advise that the puncture should be made to the side of the line of the spine, the needle taking the direction shown in Plate I. (frontispiece) with the view of avoiding the supraspinous ligament, yet the central puncture is certainly the better and less likely to go astray, or to wound the nerves and veins which lie on either side of the middle line. The same posture suffices if the injection is made into the lower dorsal region.

The operator now takes the hollow needle with the stylet in his hand. The skin over the spines is kept taut by the first and second fingers of the left hand, and the needle made to

pierce the skin with a sharp dig, its entry being controlled by a finger of the right hand. It is wise to warn the patient that he will feel a sharp prick, otherwise he will straighten his back and the course of the needle will be deflected and the line of the spines lost. The needle should be introduced between the spines inwards (forwards in this position) and slightly upwards, but kept rigidly in the middle line. As it passes through the supraspinous and interspinous ligaments, a slight holding or clinging of the needle is felt. The needle
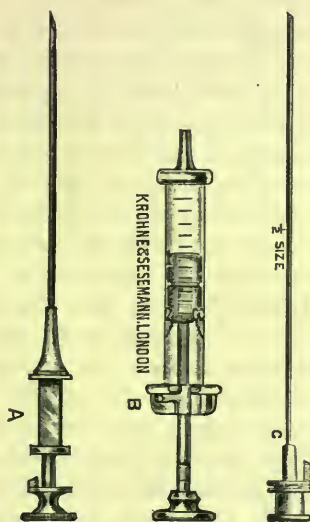
FIG. 88.—A. Hollow needle and stylet with catch which indicates the direction in which the edge of the needle is bevelled. B. Syringe. C. The cannula, also fitted with catch. (Mr. Barker's pattern.)

having entered for about an inch, the stylet is withdrawn and the needle pushed on into the canal ; as it passes through the dura, a sense of a thin membrane giving way ·is experienced.. The liquor spinalis should now escape in drops or continuously. Should no fluid come, or merely a drop or so of blood, the canal has not been entered, or the needle eye is occluded. The needle should be slightly withdrawn and again pushed home. In either case the needle should be turned, and the patient told to cough. Failing success a fresh puncture must be made, either in the same space or in the one next above. It may, in exceptional

cases, be necessary to make the patient sit up and puncture in the position shown in fig. 86. If, however, fluid freely escapes, about 10 c.c. are allowed to drop, and then the syringe and cannula are taken and the latter is passed through the hollow needle into the canal, and 1 c.c. of the stovaine-glucose solution slowly injected. This completed, the cannula and needle are withdrawn, and the puncture covered with a small piece of sterile strapping, and the patient after two or three minutes is quietly turned over on his back, his head being kept high for a few minutes longer.

Various minor mishaps may occur during the injection. There are plexuses on the posterior aspect of the body of the vertebræ and at the sides of the canal, so that if the needle is pushed too far in or is lateralised a vein may be wounded. If blunt, the needle may push the dura in front of it, and so not enter the space, or may be occluded by the nerves, which lie laterally, or by blood-clot. Again, when the needle is deviated from the middle line, it may strike the spines or laminæ, and so fail to enter the canal. The sensation of touching bone is easily recognised. It may happen that the needle's eye only half enters the dura, and in this case, although some spinal fluid may escape, yet the injection from the syringe will not enter the canal, but be dissipated in the tissues adjacent. It is essential, therefore, that spinal fluid should be seen to escape freely before injecting, showing that the dural sac has been properly entered. The cannula devised by Barker prevents this accident. It is so made that when it is driven home its end projects 1 mm. beyond the extremity of the hollow needle, and so when it is pushed home the cannula must be within the dural sac, and the fluid injected through must enter that space. To avoid rusting, Barker recommends that the cannula, needle, and stylet should be made of pure nickel. It is important also that the needle and cannula should be cleansed as soon as they have been used, and thoroughly dried, since the lumen is easily choked if it is put away damp.

The first signs of the action of the drug when injected in the sitting position are formication and analgesia in the peri-næum and upward and downward, commonly as high as the xiphisternal notch. If the patient is kept upon his side formi-cation in the feet is first noticed, and then the underlying side of the body may be analgesic, but the area supplied by the

nerves from the corresponding hemi-segment of the cord of the uppermost side may be only partially or not at all analgesic. It is best not to question the patient as to his sensation, since tactile feeling commonly persists to some extent, and he will regard a touch as tantamount to painful sensation. When the screen is placed so that he cannot see, it is easy to test sense of pain by lightly pinching the skin from the seat of injection, upwards or downwards as occasion requires, and noticing whether he evinces any shrinking or expresses his discomfort. The power of moving the limbs is not always lost although usually impaired, and the patient will move a foot if required to do so. Within the first ten minutes subsequent to the injection, pallor and sickness may occur, and the eyes may have a look of anxiety in them. Usually this passes off, although sickness in exceptional cases may recur. This faintness arises from a fall of blood-pressure, and may be due to the head and shoulders being kept in too high a position. If the effect travels high the patient may complain of want of breath and appears oppressed with marked *besoin de respirer.* Raising the feet and legs usually relieves it, and a few reassuring words will generally restore the patient's nerve. Injections of caffeine or strychnine in severe attacks may be called for while the head is kept high, and if any pillow is below the pelvis it must be removed. Blood-pressure in normal cases is not much depressed, although during such attacks as those described it is considerably lowered, the abdominal veins filling up as the abdominal muscles relax.

The analgesia usually persists for an hour or an hour and a half, but this duration varies with the patient and the dose of analgesic employed.

SACRAL ANALGESIA.

INTRASACRAL CONDUCTIVE ANÆSTHESIA—EPIDURAL INJECTION.

The method was suggested by Cathelin for treatment of sexual and other neuroses, and has been used in obstetrics, but with unsatisfactory results. S. R. Meaker * (Captain

* *Brit. Med. Jour.,* May 10, 1919, p. 569.

R.A.M.C.) has elaborated a technique and has been satisfied with the results he obtained. The dura mater terminates opposite the third, or in some cases the second, sacral segment. In the subjacent space lie the sacral and coccygeal nerves surrounded by alveolar tissue. These nerve trunks pass out of the foramina to supply the skin of the thigh and leg, buttocks, perinæum, anus, and the genitalia in part. The spinous process of the fifth sacral segment is divided, and the gap in the bone, covered with dense fibrous membrane, gives access to the sacral canal. The size of the *hiatus sacralis* varies; sometimes it reaches the fourth segment. The bony walls of the canal also vary. The canal may be very narrow, shallow, or twisted, deviations which may cause difficulties in introducing the needle. Undue force must be avoided, as the injection proposed is an extradural one and plunging the needle in may pierce the meninges.

Position of patient.—This may be prone, with the pelvis raised. Meaker seats his patient on the table with the breech over the edge, or on the left side with the right thigh fully flexed, the left less flexed. He uses preliminary medication with morphine and scopolamine. Morphine gr. $\frac{1}{4}$, scopolamine gr. $\frac{1}{150}$ two hours before, and morphine gr. $\frac{1}{6}$, scopolamine gr. $\frac{1}{200}$ one hour before, the injection into the canal. A third hypodermic (scopolamine gr. $\frac{1}{400}$) may, he says, be needed. The necessity for this and the dose given must be decided by the condition of the patient.

Technique.—The area over the hiatus sacralis is painted with iodine, and the tip of the sacrum is felt for at the summit of the anal cleft and the coccyx in the anal cleft is carefully identified, as it is quite frequently displaced laterally. The ball of the right index finger is firmly pushed upwards against the sacrum and worked slowly along the dorsal aspect of the sacrum, but without sliding the skin. The hiatus will be entered, and into the skin over the centre of this the needle, held perpendicular to the plane of the patient's back, is introduced. As the membrane closing the hiatus is sensitive, it must be rendered analgesic by injecting a little of the novocain-adrenalin solution after the skin is punctured. When the resistance offered by the membrane is felt, the free end of the needle is lowered towards the feet through an arc of 90°, so that the point of the needle is directed towards the patient's head and in the same

plane as the long axis of the body. It is pushed in the median line for about two inches, and will be felt to pierce the membrane. The needle should now be able to be moved laterally but fixed in an antero-posterior direction. If the needle is entered too near the surface, it will be superficial to the sacrum and œdema will appear. If it is allowed to enter to one side it may pierce the muscles at the side, and if it has entered the canal, the point may engage in the periosteum and become fixed. Unless the dura extends abnormally low or the needle is forced too vigorously upwards, there is little likelihood of the membrane becoming punctured and an endodural injection made. If this accident occurs it will be detected by the escape of some cerebro-spinal fluid. An extra pillow is placed below the shoulders to prevent the fluid travelling upwards. Meakin uses 20 c.c. of a 2 per cent. solution of novocain with 5 minims adrenalin (1 in 1000), *i.e.* about 6 to 7 grains of novocain, but he found that much larger doses were borne without dangerous symptoms arising.

Sacral anæsthesia is the term used by Braun for the effect produced by injections made when a long needle is introduced on the inner surface of the lower border of the sacrum and pushed along its inner surface parallel to the middle line. There is some danger of wounding the rectum, and the procedure does not appear to offer advantages compensating for the difficulties and dangers it presents.

Dangers and After-effects of Spinal Analgesia.

Deaths have occurred ; these have usually followed fall of blood-pressure with great dyspnœa, and are assumed to be due to the drug having travelled too high and affected the medulla. Rood, in the paper cited above, records two deaths, one due to stercoraceous material entering the air-passages, and one from circulatory failure in a child aged four, suffering from a gangrenous intersusception and in a state of extreme shock. He considers these fatalities were only due indirectly to the method, although he questions whether, in the latter case, the selection of spinal analgesia was a wise one. Barker and others have also recorded fatalities. The experience of the war has certainly shown that this method is dangerous in the conditions incident to war surgery. Persons who are suffering from shock or are enfeebled by age and pain are most liable to this

form of collapse, so that it is usually better to avoid spinal
injections for such patients, although when its denial commits
them to other and perhaps even greater perils a careful study
of the individual case may result in the selection of spinal anal-
gesia for even the most unpromising subjects. It is unsafe
to employ this method in the presence of syphilis or disease
affecting the cord, and in septic or pyæmic states. Age, with
the reservation given above, appears to be no bar, as even babies,
it is known, respond well to the method.* Young children are
often frightened, and unless reasons exist which render spinal
injection desirable, it is better to make them unconscious.
Elderly persons are more liable to circulatory failure, and
syncope is more common in their case, especially if the analgesia
is allowed to reach a high level. Serious heart disease and
acute febrile states are by some regarded as contra-indications.

The **mortality-rate** under spinal analgesia is also difficult
to arrive at accurately. In the practice of some Continental
surgeons thousands of cases are reported without a death,
while in some less favourable statistics the death-rate is stated
to be 1 in 200. When we compare such statistics with those
of general anæsthetics, we find much the same discrepancies.
In the case of experts, thousands of cases are given with no deaths ;
but when the general death-rate is arrived at by adding the
hospital or other figures, which include the work of skilled
and unskilled anæsthetists, the mortality-rate becomes less
favourable. It is stated by those who have made a special
study of such figures that at present the mortality under spinal
injection is higher than that under chloroform. Too much
importance, however, must not be attached to either set of
statistics. It is probable that in really serious cases some deaths
will occur whatever method is adopted, and undoubtedly it is
the duty of the anæsthetist to select that method which appears
to him to hold out the best chances for the patient's ultimate wel-
fare and immediate comfort. Again, the enthusiastic advocates
of this method are apt to urge its adoption to avoid sequelæ
which they allege always follow the use of general anæsthetics.
Here again what has been said above also applies. While dangers
and serious discomfort or suffering may follow the use of general

* The dose for children is relatively larger for infants than for adults.
It is decided by the age and physique of the child. Rood gives 2·5 centi-
grammes of stovaine to babies and children up to two years old (*op. cit.*).

anæsthetics, they do not by any means form a necessary part of the evolution of the anæsthetic state, any more than those dangers and discomforts rehearsed as possible sequelæ of spinal injection represent the inevitable course of symptoms induced by that method.

The relative safety of the methods of spinal and general anæsthesia is largely a question of experience and the ability to make an accurate choice between them in any given case. Spinal analgesia possesses the great advantage of producing relaxation of the musculature, and this in the case of a complicated operation upon the abdomen or in the pelvis is of great importance, but it has the disadvantage that it does not make the patient unconscious. We have therefore to reckon with the danger of psychic shock arising during spinal analgesia.

In order to utilise the method's great advantage and minimise its defect, it is better to combine spinal analgesia with general anæsthesia, whenever this is possible. The anæsthetised patient is spared the alarming " prick in the back," and the stress imposed upon him by the knowledge that a prolonged operation upon him is in progress. The surgeon is saved the necessity for silence and hurry, and is assured of an unconscious as well as a relaxed patient. The amount of general anæsthetic required is small, and the after-effects of the combined methods compare favourably with either method when pursued by itself.

Complications arise : (*a*) From the injection ascending too high. The breathing may cease, but is usually restored by compression of the chest and oxygen inhalations. (*b*) Fall of blood-pressure. Rood has met with three cases in which the respiration stopped owing to syncope, sudden pallor occurred, the patients lost consciousness, gasped and ceased to breathe. (*c*) Vomiting during the operation. This occurs most frequently in cases of high anæsthesia. (*d*) Pulmonary complications are not frequent, but do occur.

Treatment.—Artificial respiration performed by perflation or hand-pressure on the chest is better than other plans. Pressure on the aorta or heart massage, when the abdomen is open, also raising the arms and legs and injecting hot saline into the rectum . if the heart is not accessible, represent the line of treatment most likely to assist. Warmed oxygen helps in minor degrees of circulatory or respiratory difficulty.

As to the **sequelæ** it is impossible to speak with certainty, as undoubtedly many of the most serious after-effects, such as persistent and intense headache, vesical paralysis, loss of rectal control, paraplegia, septic spinal meningitis, ocular palsies, which have been recorded, may have been caused by faulty technique. However, really severe headache, persisting vomiting, and paresis of the external rectus muscle of the eye, though not common, do occur, and must be borne in mind as possible results.

Suitable cases for spinal analgesia.—Formerly it used to be taught that, when a patient's condition was too bad for him to take a general anæsthetic, he should be given an intradural injection. That belief cannot now be held. The general anæsthetic can now be administered by safer methods and with more safeguards than formerly, and only a few cases, such as those of diabetes, are unsuitable for general anæsthesia. It may fall short of the requirements of the surgeon, and then can be usefully combined with intrathecal injection. "Acute abdomen" certainly calls for spinal analgesia, but even for this condition it is desirable at times to associate general with spinal anæsthesia. It cannot be doubted that spinal methods, like the methods of general anæsthesia, have their dangers and are answerable for some degree of shock, so that the choice between the two is often one of great difficulty; and whereas a general anæsthetic can be withdrawn if taken badly, the analgesic once injected cannot be removed and its effects persist. It is probable that spinal methods should be regarded as adjuvant, rather than as alternative to, general anæsthesia. It seems definitely proved that in war surgery their use is usually contra-indicated unless the conditions existing are practically the same as those obtaining in civil hospitals.

In cases in which the blood-pressure is initially low or is likely to become greatly depressed by the operation, spinal methods are undesirable. On the other hand, limitation by age, formerly excluding babes, children, and old persons from the advantages of spinal analgesia, is now swept away by our more extended knowledge. In cardiac disease, especially when, as in aortic trouble, syncope is liable to occur or the blood-pressure is unstabilised, spinal methods are dangerous. Pulmonary disease does not present such contra-indications unless it is associated with heart disease.

In cases when fæcal vomiting is feared, also in diabetics and in cases of advanced renal disease, the intradural injection of drugs has not proved as beneficial as was at one time expected. Whether its dangers are less or merely equal to those associated with the use of general anæsthesia in the hands of experts it is at present impossible to say. It seems probable that local infiltration methods, with or without the use of alkaloids, possibly associated with a form of light narcosis *e.g.* nitrous oxide and oxygen, will be found to offer the most judicious choice of methods for such complex cases.

Choice of Analgesics.—Most authorities have ruled out cocaine and alypin as too dangerous. Stovaine, novocain, and tropacocaine may probably be taken as regards reliableness and safety in the order named, although some Continental surgeons have adopted novocain in preference to stovaine, and have relied upon the use of adrenalin in conjunction with it. Dr. Rood states that novocain does not give such complete relaxation as does stovaine. Those who accept the diffusion theory of the conveyance of the drug along the canal adopt a light as against a denser solution. Dr. Rood * found that in saline solutions of stovaine, " irrespective of the position of the patient, the stovaine diffused about 10 inches upwards from the point of injection and equally on both sides of the body." It is impossible to limit the action of the drug in such solutions, and the analgesia produced was more transient than in the case of heavy solutions, so that larger doses of stovaine were required.

Solutions for lumbar injection.—Ampoules for this purpose are supplied with the following strength :

Novocain, 0·15 grm. ; adrenalin borate, 0·000,325 grm. This supplies 3 c.c. of a 5 per cent. solution of novocain ; of this 2 c.c. to 3 c.c. are injected.

Tropacocaine in 5 per cent. solution, with or without adrenalin, is extensively employed.

Stovaine, 5 per cent. ; glucose, 5 per cent. These ampoules contain 2 c.c., of which one is measured off in the syringe, and is the average dose for the adult. This, of course, equals 0·05 gramme (5 centigrammes) of stovaine.

The syringe is filled by inserting the cannula fixed on it into the broken end of the ampoule. The instrument is then turned with the cannula upwards, and tapped in order that any bubbles

* *Op. cit.*

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and all the solution in excess of the exact amount required may be expelled.

ANALGESIA PRODUCED BY FREEZING.

Ether spray * (Sir B. W. Richardson).—The woodcut (fig. 89) explains the simple mechanism of this contrivance.

The analgesia so obtained is confined to the skin, and is very transient. Recovery of sensation when the spray ceases to work is often accompanied by very painful smarting and tingling. The great drawback to the method is that the instruments and skin get thickly coated with ice, which obscures
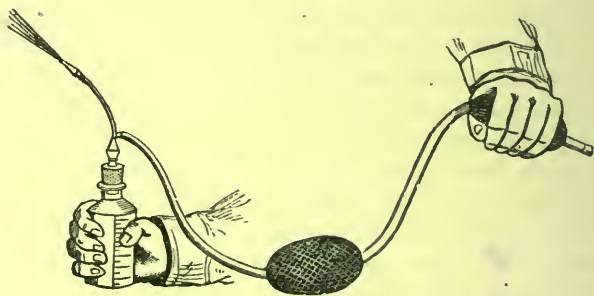
FIG. 89.—Ether spray.

the parts, rendering the use of the knife almost impossible. Further, under ether spray it is difficult to see and secure bloodvessels, and painful to do this when the analgesia has passed off. Unless care be taken, the skin may be so much frozen that a slough like that of frost-bite will follow.

Various agents have been employed which produce a certain degree of analgesia by freezing the tissues upon which they are sprayed. We may mention **methyl chloride** and **ethyl chloride. Coryl** is a name given by G. Joubert to ethyl chloride mixed with methyl chloride so as to lower its boiling-point from 10° C. to 0° C. ; **Anesthyle** is the name given by Dr. Bengué to a mixture of 1 part methyl chloride to 5 ethyl chloride—its use is similar to that of coryl ; **Rhigolene,** a product of the

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* Richardson recommended anhydrous ether, sp. gr. 0·720, mixed with an equal part of hydride of amyl (rhigolene).

distillation of petroleum, was introduced by Richardson, who employed it with ether in his atomising spray.

These substances are kept in tubes with specially constructed stop-cocks, which allow of spraying over the area to be frozen. A large number of drugs have been proposed as local analgesics, but as few have special advantages, no further mention need be made of them here.

Faradic currents directed for some minutes through an area of skin or mucous membrane produce some degree of analgesia. At one time this method was in vogue among dentists; it has now fallen into disuse. A recent attempt has been made to revive this plan, improved apparatus being employed, but the success achieved seems to have been so slight as to make it hardly necessary to particularise its features.

CHAPTER XII.

MEDICO-LEGAL ASPECTS OF THE ADMINISTRATION OF ANÆSTHETICS.

LEGALITY OF ANÆSTHETISING PATIENTS.

In the present state of the law there is no restriction imposed upon anyone with regard to the giving of anæsthetics. A further anomaly exists with respect to such powerful drugs as cocaine. Their use undoubtedly requires at least as much acumen as does a general anæsthetic, but unqualified dental practitioners habitually employ cocaine without let or hindrance, and even when the unhappy patient dies as a result of ignorance or lack of skill, the offence is dealt with as though the procedure were an absolutely justifiable one, although the result was unfortunate. If, as a medically qualified man, a person gives an anæsthetic carelessly, or reveals complete ignorance, he becomes guilty of malpraxis, since a medical practitioner is expected to know how to administer an anæsthetic, this being part of his profession. He is also debarred, save under exceptional circumstances, from permitting an unqualified person to give an anæsthetic to any of his patients, and he is forbidden to give an anæsthetic for an unqualified person such as a " bonesetter," unregistered dentist, and so on. If an unqualified person gives an anæsthetic, or applies an analgesic, and does not represent himself to be a person duly qualified by law, he only comes under legal censure if his patient suffers injury as a result of such an action. These persons are commonly dealt with very leniently, and only suffer if the judge considers that they failed to act with what he considers to be reasonable skill and knowledge, even although it is recognised by medical men that giving an anæsthetic must be dangerous unless the administrator has received instruction, enjoyed experience, and studied the human frame from the side

of physiology and pathology. The unqualified person usually in his case has none of these advantages.

Germane to this matter is the revived suggestion of handing over the administration of anæsthetics to a more or less trained nurse. Although there is some difference of opinion in this country, abroad, and in the United States, as to the advisability of nurses acting as anæsthetists, there can be no question, from the legal aspect, that any medical man who permits a nurse, since she is an " unqualified person," to give an anæsthetic, except in cases of emergency, is guilty of an act of " covering." If such a legal trespass is condoned in the matter of anæsthesia, it is hard to conceive why similar condonation should not be extended to nurses who undertake the functions of a physician, surgeon, or pharmacist. This matter is referred to later on.

The **administration** of an **anæsthetic** to a **patient** who is not a minor, **against his will,** constitutes an **assault.** When a patient has voluntarily submitted himself to be anæsthetised he may, under the influence of terror, during an early stage of the proceedings, attempt to prevent further narcosis ; he is then not sufficiently guided by his reason, and the administrator is bound, in the patient's interest, to take his own course.

The qualified anæsthetist, like any other medical man, is liable to prosecution for **malpraxis** ; it then rests with him to prove that whatever steps he took were adopted after due consideration, and because he believed them to be the best he could follow in the interests of his patient. Such questions as the following might arise : Did the anæsthetist undertake a duty which knowledge, skill, and experience had qualified him to fulfil ? Did he employ the most suitable agent according to his view of the exigencies of the case ? and did he administer it with due skill and by an approved method ? Did he possess himself of all the necessary facts with regard to the patient's bodily condition ? and did he make due allowance for these in the treatment which he pursued ? In the event of an accident of any kind, did he adopt the right and appropriate treatment indicated in such an emergency ? and was this done with due promptitude ?

Anæsthetics have been employed to assist in the **perpetration** of **various crimes** upon the person narcotised. Thus, it is alleged, an anæsthetic may be given without the consent of a person ; or, if it is given with his or her consent to effect a

lawful procedure, advantage may be taken of the anæsthetised person's helpless condition to perpetrate a crime.

Can an **anæsthetic** be **administered without consent** ?—Firstly, can this be done whilst a person is awake and in full possession of his senses ? Formerly many cases came into the law courts, in which the complainant alleged that a handkerchief saturated with chloroform was waved before his face and unconsciousness followed *immediately*. This we now know to be an impossibility ; a period of time varying from two to twelve or more minutes must elapse before an individual passes under the influence of chloroform, and during this time fresh supplies of the anæsthetic are needed. Further, chloroform, in most cases, produces so much excitement that one person would find it a difficult matter to keep the victim sufficiently still to complete the anæsthesia, and could hardly do so without there being both noise and disarrangement of the victim's clothing. Further, unless food is avoided before the anæsthetic is given, vomiting is very liable to occur, and with it a return to consciousness.

It is often alleged by the supposed victim that he, or she, was conscious of what was being done, but was powerless alike to speak or resist. Such statements must be received with the utmost caution. It is true that Péan recorded cases in which patients, although rendered analgesic by ether, retained their consciousness as to what was in course of proceeding. Cases like Péan's must be so exceptional that one is tempted to believe the anæsthetic was administered very imperfectly, and that faith in the assurance of the surgeon did the rest. Snow also admitted the possibility of persons imperfectly chloroformed being conscious and yet powerless to resist. The condition miscalled " analgesia " obtained by inhaling nitrous oxide and oxygen which is carried to a degree short of unconsciousness is similar, and persons drowsed in this manner are indisposed or unable to move their limbs while the state of narcosis persists. In attempts at criminal violence under an anæsthetic administered without the victim's consent, fear, excitement, and struggles would all be against the possibility of arriving at loss of voluntary power without deep narcosis. It is very doubtful whether a person, be he an expert or not, could narcotise a waking adult against his will unless there existed a very unusual disproportion between the physique of the two individuals. In the case of R. *v.* Snarey the prosecutrix alleged that she

had been rendered insensible instantly by something being held over her face upon a handkerchief, and that in that condition she had been violated. This contention could not, in the present state of knowledge, be admitted by experts. However, in a parallel case, that of White *v.* Howarth, the prosecutrix made a similar assertion, and added that she was aware of what was going on, but was unable to resist.

Although the time required to thoroughly anæsthetise a patient is longer when chloroform is used than when ether is employed, yet, from the highly irritating nature of the vapour, ether is less easy to administer to an unwilling patient than is chloroform. And further, ether, if its action is to be obtained rapidly, requires the use of some apparatus more or less excluding air, and hence is less easy to manipulate by those who are not experts. In general it may be affirmed that, if it is not easy to use chloroform for criminal purposes, the employment of ether presents greater difficulty. In a case reported it was alleged that a burglary was carried out by men who chloroformed the owner of the property as he lay in bed, and then ransacked the premises. The presumption must always be against the truth of such statements. Persons left to guard banks and other places containing valuables have on several occasions affirmed that they were rendered unconscious by chloroform while a robbery was carried out. It is inevitable, in such cases, that the story should be doubted, and indeed the persons uttering it have been shown in some instances to have been the actual depredators.

CAN A PERSON BE ANÆSTHETISED DURING SLEEP?

Dolbeau made careful experiments with reference to this subject, and his conclusions are certainly consonant with the experience of most skilled anæsthetists.

He first attempted to anæsthetise four persons during sleep. Three were awakened during the process. In his second series of cases four persons out of six awakened, and in his third series only three persons awakened out of nine to whom he administered chloroform while they slept. Dr. Turnbull asserts that either chloroform or ether may be given without awakening the subject of the experiment. I have no doubt that chloro-

form may in some cases be so administered, but am less sure
about ether ; in either case certain conditions must be present
to ensure success. If the patient has been drugged by alcohol,
morphine, or is under the influence of grave shock or great
fatigue, anæsthesia can be produced without arousing him from
stupor. The greatest care, skill, and familiarity with the anæs-
thetic used might enable an expert to succeed, and then pro-
bably only in the case of a heavy sleeper. Dr. Leonard Guthrie
repeatedly tried to chloroform children in their sleep, but he
never succeeded.

A further question arises, upon which evidence may be sought,
and that is whether, in the event of his escaping capture, it
is possible to prove the person attempting to administer an
anæsthetic with criminal intent was one skilled in its use. To
determine this offers some difficulties. The presence of appa-
ratus, the method in which lint or a handkerchief is folded,
or blistering of the lips and nose from allowing the chloro-
form to drop upon the face, might offer a clue. If ether is
employed we may be sure that the person using it possessed
some knowledge, especially if he had used a formal apparatus
which was accurately fitted and filled, since ether given by the
open method seldom if ever carries the patient beyond a stage
of delirious excitement, unless skilfully handled, and produces
bellicose struggles such as would effectually prevent the accom-
plishment of any criminal design.

Anæsthetics have been given to assist in the committal of
ROBBERY, RAPE, and MUTILATION. What has been said above
leaves little to add with regard to robbery. Cases have oc-
curred of persons who, it was alleged, were rendered irresponsible
for their actions for some weeks, or longer, after taking an
anæsthetic. Such instances of temporary insanity are very
rare, but may arise among the neurotic, and those whose family
history reveals a tendency to mental instability.

In a case in which the writer was called upon to give expert
evidence, a highly respectable young man was charged with in-
decent exposure. The defence, which was accepted by the judge
as conclusive, was based upon the fact that the defendant's
mental poise had been upset as a result of inhaling an anæs-
thetic some time before the offence was committed. The family
history was one of marked mental infirmity.

ATTEMPTED RAPE UNDER ANÆSTHETICS.

Many cases have now been reported in which the prosecutrix has affirmed that a dentist or medical man has violated her person while she was under the influence of an anæsthetic. So frequently are such charges advanced that the greatest care should be taken in order to ensure the presence of a third person at least within earshot and preferably within sight of the administration of the anæsthetic. No administrator of an anæsthetic is safe from having such a charge preferred against him, and if he and his supposed victim were alone it is simply a case word against word. Further, the woman may be *enceinte* at the time of the alleged rape, and may subsequently give birth to an infant, whose parentage she may find it convenient to foist upon the medical man.

But it is not only designing bad women who make such accusations : modest, virtuous, and refined gentlewomen have figured in these cases. The cause for this remarkable and deplorable state of things is fortunately not far to seek. Chloroform, ether, possibly also the other carbon compounds employed in producing anæsthesia, nitrous oxide gas, and even cocaine and novocain, possess the property of exciting sexual emotions, and in many cases produce erotic hallucinations. It is undoubted that in certain persons sexual orgasm may occur during the induction of anæsthesia. Women, especially when suffering from ovarian or uterine irritation, are prone to such hallucination, and it is almost impossible to convince them, after their return to consciousness, that the subjective sexual sensation had no objective origin. It is stated that women at their menstrual periods are more prone to erotic hallucinations than at other times, a theory which may be borne in mind. A case cited by Sir B. W. Richardson will illustrate this statement. A young lady had chloroform administered to her by a doctor in the presence of a dentist and of the young lady's mother and father. After a tooth had been extracted, and the patient had become conscious, she steadfastly affirmed that she had been criminally assaulted by the dentist, and to this statement she adhered, although the four persons present in the room strove to disabuse her mind. It is stated that in the case of cocaine and its congeners the hallucination does not develop until

some little time after the injection of the drug, and so may
not be mentioned until the patient has reached her own home.

In considering the evidence in such cases, the following points
need special attention :—

Nature of the anæsthetic.—Chloroform, ether, and the other
members of the carbon anæsthetic series, certainly render
persons wholly unable to protect themselves from any personal
ill-usage. The body of the anæsthetised patient is, however,
rendered utterly flaccid, and is a dead weight. If, then, there
is any question of moving the body—as, for example, from
a dental chair, and again back into the chair—it must be re-
membered that such an undertaking would be exceedingly
difficult for one individual, however strong, and could hardly be
accomplished without causing much disarrangement of clothing.

On the other hand, if the offence was alleged to have been
committed when the patient was under the influence of nitrous
oxide gas, it would have to be borne in mind that the effect
of this gas is to produce, first muscular rigidity and subsequently
violent jactitation. Further, unconsciousness only persists for
about half a minute, or, in exceptional cases, a trifle longer,
and the patient regains her senses with control over her muscles
in a few seconds. This being so, it is exceedingly improbable
that even a premeditated and skilfully planned attempt at
violation would be successful if made upon a woman under
the influence of nitrous oxide gas.

A caution is needed about admitting the evidence of a person
only just recovered from an anæsthetic. The following case
illustrates this : A dentist appealed to a friend to extract a
tooth. Under gas he struggled so violently that the operation
was not attempted, but, as he came to, he reproached his friend
most bitterly, telling him he had felt the whole pain of the ex-
traction and was even then suffering torture !

**Civil actions for damages have occurred in connexion with
operations under anæsthesia,** in which the patient has sought
to recover compensation for such injuries as burns due to hot-
water bottles, paralysis of limbs due to faulty posture, and even
for operations undertaken without full consent of the patient,
in which the anæsthetist was held to be an accessory. It is
obvious, however, that unless he made himself personally
responsible, the anæsthetist would not be mulcted for any
alleged torts of his surgical confrère. It is, however, his duty

to exercise a general supervision over the patient's condition, posture, and so on, although from the very nature of things it is the surgeon who would decide the position of the patient and the extent and nature of the operation undertaken. In cases which have been before the Courts, the anæsthetist as well as the surgeon and those responsible for the nursing of the patient have been cited as defendants.

The decisions arrived at have been determined by the particular circumstances of the individual cases and the responsibility which those taking part in the operation and attendant proceedings actually if tacitly accepted. Thus an anæsthetist, while attending to the general welfare of the patient so far as the anæsthetic was concerned, could hardly accept the responsibility of procedures the result of the surgical manipulation, nor of injuries arising from the heedlessness of a nurse whose duty it might be to place hot-water bottles or render other assistance subsidiary to the carrying out of the operation.

If the operation performed were of an illegal nature, or if the patient in the hearing of the anæsthetist restricted the extent of the operation, the anæsthetist might be held responsible as an accessory if he aided in any illegal procedure.

DEATH UNDER AN ANÆSTHETIC.

It becomes requisite to decide whether the death was suicidal, accidental, or followed an anæsthetic given by a person other than the deceased ; and then whether the individual who actually administered the anæsthetic was competent to give it. Chloroform is frequently used as an anodyne, and many deaths have resulted from accidents, such as the soaking of the patient's pillow with chloroform. The presence of a phial near the corpse might point to self-administration. Ether is not used similarly, and is not commonly selected by suicides, although ether-drinking is practised in some districts. One death from nitrous oxide gas, in similar circumstances, is reported from America. A dentist, whilst under the influence of drink, placed himself in his chair and, turning on the gas, held the face-piece over his mouth and nose. In the morning he was found dead, and the gasometer empty. A somewhat similar case has occurred in England.

It is important to carefully search for evidence as to *how*

the anæsthetic was administered, as this may determine whether it was done *secundum artem* or unskilfully.

The **inquiry** into a **death** supposed to be from an **anæsthetic** commences with the question—Was death due to the anæsthetic, to hæmorrhage, shock, exhaustion, or to some other complication following the surgical operation ? The mode of death due to chloroform, ether, and other agents, is described under the heading *Chloroform*, etc.

The consent of the patient, or of his guardians if a minor, must be established unless it can be shown that the operation and the anæsthetic were necessary to save life, and were undertaken under the stress of an emergency which precluded delay. The more difficult question arises when the patient who is desperately ill declines an anæsthetic through fear, while his friends desire that every step which is necessary to give him a chance of life shall be carried out. It is unquestionable that, unless the patient's mental condition is obviously not such as to make him capable of a responsible decision, his wishes must be respected. If, however, he is for the moment *non compos mentis*, his position in refusing the anæsthetic and operation is akin to that of a would-be suicide, and warrants some effort to save his life even against his will.

The CHOICE of the ANÆSTHETIC would have to be JUSTI-FIED : thus, were chloroform given for a simple tooth extraction in lieu of the safer agent—nitrous oxide gas—and were the patient to succumb, the administrator would have to explain why he selected the more dangerous agent, and what physical conditions existed which justified him in his choice.

All anæsthetics involve some danger. In the hands of one skilled in their use this danger is minimised ; but, whatever may be the individual uses and opinions, the general consensus of belief places anæsthetics in the following order of safety : nitrous oxide gas when used for short operations ; ether ; ethyl chloride ; chloroform. The position as to safety of analgesics in spinal analgesia may be taken as stovaine, novocain, tropacocaine, cocaine, alypin. Other substances are not used sufficiently often to make statistics reliable, but the following table gives a rough estimate of their danger * :

* No great stress can be laid upon these figures, as in many cases a death occurred very early in the career of an anæsthetic, and this rendered further trials of it inadvisable.

TABLE SHOWING DEATH-RATE UNDER THE VARIOUS
ANÆSTHETIC AGENTS.*

		Deaths.	Administrations.
Chloroform (Coles, Virginia) . . .		53	152,260
,, (Richardson) . . .		1	2,500 to 3,000
,, Baudens (during Crimean War)		1	10,000
,, War of Secession . . .		1	11,448
,, Gurlt (Reports in Germany, 1895 and 1896) . .		29	34,401
,, Julliard (Geneva). . .		161	524,507
Ether (Andrews)		1	23,204
,, Julliard (Geneva) . . .		1	14,987
,, Lee (Chicago)		4	92,816
,, Gurlt (German Hospitals, 1895 and 1896)		3	13,008
Nitrous Oxide Gas (alone or with air, mostly dental cases)		1	20,000 †
,, ,, ,, (another estimate) .		1	100,000
Nitrous Oxide and Oxygen (surgical cases)		1	10,000 †
Ethyl Chloride		1	8,414 †
Amylene		2	238
Hydrobromic Ether		2	600
A.C.E. mixture, No. not ascertainable ‡			
Chloroform-ether sequence . . .		1	8,027 †
Methylene mixture		1	5,000
Spinal Analgesia		1	3,500 †

[N.B.—The statistics concerning spinal analgesia vary within
very wide limits. Hohmeier gives deaths as 1 in 200, while
Tomachewski suggests 1 in 17,847 cases.]

It must be added that Scotland presents a series of statistics
much more favourable to chloroform; thus, out of 36,500

* The Report of Anæsthetics Committee, Brit. Med Assn., July 1900,
gives 18 chloroform deaths in 13,393. These are classified as 3 due wholly
to chloroform, 4 principally to it, and 11 doubtful. Under ether 6 deaths
in 4,595 cases, but none entirely due to the anæsthetic.

† These figures are given by Dr. Gwathmey, " Anæsthesia," pp. 844 et seq.

‡ Richardson states erroneously that no death has occurred under A.C.E.
mixture. Dr. Reeve of Dayton, Ohio, reports three deaths, and several
others have been recorded.

administrations at the Edinburgh Infirmary during ten years, only one death has been recorded. Inquiries recently made have revealed that several deaths from chloroform have occurred at the various surgical centres of Scotland, so that the above estimate can no longer be taken as a reliable statement of the death-rate from chloroform.*

Dr. McEwen gives his own results at Glasgow (computed, not recorded) as 11,886 cases of anæsthetics, 500 of which were ether cases. He makes various deductions from his total, and regards 10,000 with one death as his chloroform record. Sir George Macleod mentions 15,000 cases with one death, and Dr. Buchanan 9,000 with one death. This gives the total of 34,000 with three deaths, or about one in 11,000, for three leading Scotch surgeons. This estimate cannot be taken as representing accurately the death-rate under chloroform in Scotland at the present time.

In considering the figures given above, which represent the death-rate of the past rather than of the present, the method employed has to be taken into account. If we could obtain the statistics of trained anæsthetists, we should find the mortality under any anæsthetic much below the figures given. However, such statistics are unprocurable. Further, modern methods are superior to those employed a few years ago, and so the use of all anæsthetics is much more safe, and the absolute mortality is below the former expectancy.

QUESTIONS OF RESPONSIBILITY.

These arise when the patient dies under an anæsthetic, and may involve the question as to whether the most suitable anæsthetic was employed and by the best method. Sometimes a patient refuses one anæsthetic, preferring another ; here the administrator clearly cannot shirk responsibility, but must give that agent which he deems best if actual danger is involved in deferring to the wish of the patient. In the converse case, when death occurs during the administration of an anæsthetic which the patient declined to take until persuaded, cajoled, or forced into taking, the anæsthetist would have to show that his special knowledge guided him in making his selection, which,

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* No Coroner's Inquest is held in Scotland upon " Deaths under Chloroform," hence their occurrence does not obtain publicity.

although it led to a fatal result, was, in point of fact, the best choice he could make in the patient's interests. In the employment of a new or untried anæsthetic, very grave responsibility would rest with the administrator unless he very fully and clearly explained the possible results, and obtained the patient's consent to the trial.

A question which we have not yet fully considered arises— Who, in the eye of the law, is qualified to administer an anæsthetic ? At present some uncertainty exists upon the point, owing to discretionary power being left to the operating surgeon to assume the responsibility of the anæsthetic. Thus nurses, students, butlers, coachmen, dispensers, and various unqualified persons have been frequently permitted to give the anæsthetic, or, as the phrase is, " keep it going," while the surgeon, besides operating, is supposed to exercise a general supervision over the administrator's proceedings. If any accident happened the death certificate would have to be signed by the surgeon, and the Coroner's Court might admit the principal's evidence. It cannot be doubted that, to give any individual an anæsthetic subjecting him to a minimum of danger is all one person can do, and can only be accomplished by those specially instructed and experienced in the use of anæsthetics. Were an action for damages brought concerning a death occurring under the aforesaid circumstances, there is little doubt that the persons proceeded against might be heavily mulcted, since nothing short of the utmost emergency could justify the proceeding.

The more stringent view now taken by the General Medical Council with respect to " covering " renders the position of a qualified medical man who allows an unqualified person to assist him by administering an anæsthetic an equivocal one. Unless it could be shown that the aid of a second qualified medical practitioner could not be obtained, or that delay was detrimental to the patient, the question of " covering " would arise, and the medical man would incur the risk of having his name struck off the Medical Register. The similar case, that in which a medical man has given an anæsthetic for an unqualified person who performs the operation, has been decided by the General Medical Council ; the name of the medical man being struck off the Medical Register.

Recently an action for malpraxis was brought in a Colonial court against a medical man who had administered chloroform

to a patient with a fatal result. The question rested upon whether the anæsthetic was rightly and skilfully given, and, this being taken as proved, the Court decided the case in the medical man's favour.

In another case the medical man administered the anæsthetic (chloroform) without assistance, and proceeded to operate. The patient, however, died, and an action for damages was brought and eventually decided in the medical man's favour. The line of defence adopted was (1) the medical man was duly qualified ; (2) chloroform was necessary ; (3) the operation being slight—moving a joint—the presence of a second doctor was unnecessary ; (4) all was done which experience and knowledge demanded ; (5) the death was unavoidable, and not due to carelessness or want of skill. Expert witnesses were called for the defence to show that the anæsthetic used was a suitable one, and that it was properly administered. When a medical man **gives** an **anæsthetic** and **operates single-handed** as in the case cited, he undoubtedly places both his patient and himself in a dangerous position. Unless emergency can be pleaded, it seems probable that the question of justification would be decided upon the merits of each case and upon the status and recognised skill of the practitioner.

Should Dentists give Anæsthetics ?

How far dentists practising with or without the L.D.S. diploma are legally justified in administering anæsthetics is a moot point. Many hold that the L.D.S. confers a right to the administration of nitrous oxide gas, but no other form of anæsthetic. In the United Kingdom, I believe, no trial case has been contested. The ground for this affirmation that licentiates in dental surgery possess such a right has no legal basis, but has grown out of the belief that the use of nitrous oxide gas is part and parcel of the dentist's calling, and that so he has a right to employ it. This, however, applies with equal force to all registered dental practitioners. Probably the issue would rest, in the present ambiguous state of the law, more upon the experience and recognised skill of the person administering the anæsthetic than upon the nature of his qualification. If it be shown that a registered dental practitioner *sine curriculo*, after two or three thousand successful adminis-

trations, met with an accident, in spite of all due care and precaution, he would probably be in a better position than would a practitioner with a diploma who met with a fatality, presumably through maladroitness, if it were proved that he had never obtained a practical experience in giving anæsthetics. As has been stated above, there is no law forbidding anyone, whether registered as a medical man or not, from giving anæsthetics, but if injury or death follows his so doing he would certainly run the risk of being found guilty of malpraxis or manslaughter.

In any case, a person would be open to grave censure, if not liable for malpraxis, were he to undertake the administration of an anæsthetic, and operate single-handed, unless it could be shown that to do so was a necessity, no help being available. Dentists on the Register are, of course, under the same regulations as regards covering as those obtaining in the case of a medical man.

Legal Responsibilities of Anæsthetists.

It has been made a subject of much debate—with whom rests the responsibility of the choice of the anæsthetic : with the surgeon who operates, or with the anæsthetist who gives the anæsthetic ? Clearly this must depend entirely upon the understanding which exists between the two. If the anæsthetist is called in, as an expert, to decide what anæsthetic is best for any given patient, his must be the sole responsibility ; while if an anæsthetist is present simply as an assistant to the surgeon to give in the best possible way an anæsthetic which is named by the latter, his responsibility can extend only so far as the actual administration is concerned. If the two disagree, the surgeon, insisting upon an anæsthetic which the anæsthetist conscientiously believes will jeopardise the patient's life, cannot cover the anæsthetist ; and the latter has but one course to adopt, namely, to retire from the case. As the experience of the surgeon may equal or exceed that of the anæsthetist, especially if the patient is well known to the surgeon, to retire from the case would be a grave step for any anæsthetist to take, and only justifiable in extreme cases. When doubt exists, the right course is for the surgeon and the anæsthetist to meet and hold a consultation, when the questions

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of the choice of the anæsthetic and the method should be discussed deliberately from the two points of view. The fact that the anæsthetist is a duly qualified medical man, and so is personally responsible for his professional procedure and skill, must not be lost sight of; and it precludes him from claiming exemption from blame if the patient suffers from the effects of the anæsthetic, even though the surgeon may be willing to accept full responsibility in the matter.

Covering.

It has been decided by the General Medical Council that any medical man who gives an anæsthetic for a person who does not, in fact, possess the right to practise as a dentist is in the eyes of the Council guilty of the offence of "covering." Similarly, giving anæsthetics for unqualified bonesetters or unregistered surgeons has been definitely pronounced to constitute an act of " covering," and so carries the penalty of that offence. The kindred case of a qualified medical man inviting an unqualified assistant to give an anæsthetic has frequently arisen. As has been pointed out above, unless it can be shown that the help of a second qualified practitioner could not be obtained the qualified practitioner might be liable to an indictment for " covering."

Anæsthetics for Illegal Operations.

How far, in the eyes of the law, an anæsthetist would be regarded as an accomplice to the operator is at present undetermined by judicial decisions. In the event of the anæsthetist becoming acquainted with the nature of the proposed operation before the anæsthetic was given, he would certainly be incriminated if he then assisted in the performance of the operation by administering the anæsthetic. Whilst it is not the business of the anæsthetist to inquire into the nature of any operation, or to criticise the way in which it is performed, he should make himself acquainted with the fullest details of the case if he has his suspicions aroused. When any doubt is present in his mind as to the legality of the operation, or as to the *bona fides* of the person conducting the case, he will do wisely to retire from it, as his presence gives his tacit con-

sent to the operation, and would probably place him in the same position as the operator should legal prosecution follow. It need hardly be pointed out that the anæsthetist shares in no way the legal responsibility as to the advisability of an operation, the manner in which it is performed, its success or failure, save and except in so far as these may be involved in the manner in which he has conducted the administration of the anæsthetic. An exception to this arises when the anæsthetist becomes acquainted beforehand with any facts which make it evident that the operation is a fraud, or undertaken to obtain money by false pretences, and is not one which would be performed by any recognised authorities upon the subject. Under such circumstances the anæsthetist has but one course open to him; viz. to retire from the case.

DEATH FROM NITROUS OXIDE GAS.

The deaths which have occurred when the patient had inhaled or was inhaling this gas cannot be imputed to any specific action it exercised. In some cases heart failure occurred upon the patient's resuming consciousness *before the operation was completed*, and in others respiration was interfered with by gags slipping, and setting up laryngeal spasm. Unquestionably there is danger if the patient is allowed to feel pain, especially in operations upon the fifth pair of nerves ; but little, if any, when the gas is given fully, and the operator warned to desist before consciousness returns. In one case an elderly lady died under this anæsthetic. She was wearing extremely tight corsets, her heart was diseased, and her stomach contained food ; moreover, the gas was administered twice. It has been stated * that, when nitrous oxide and oxygen are given together, acute dilatation of the heart takes place, and fatal results follow if chloroform is given after this mixture.

The post-mortem appearances are simply those of death from syncope, or of death from asphyxia.

DEATH FROM ETHER.

Ether, when swallowed, gives the following symptoms. The patient is lethargic or comatose, breathing slowly, deeply, and with stertor ; the skin is pale and cold, and covered with

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* *Proc. Soc. Anæsth.*, vol. ii., p. 179 (see above, p. 122, Case III.).

clammy sweat. The exposed mucous membranes will be purplish, the face livid ; the pulse quick, soft, small, and compressible. Complete muscular relaxation gives the body a flaccid, doughy feel. The eye is fixed and glassy, and usually smeared with ja thick film of mucus, the pupils are dilated and insensitive to light. The body temperature is depressed several degrees below the normal.

- The symptoms detailed may be brought on in from three to five minutes. Six drachms to an ounce are necessary to produce narcotism when swallowed. Ether, when swallowed, has not caused death in the human subject (Taylor). Orfila, experimenting upon dogs, found the mucous membrane of the stomach of a black-red colour, acutely inflamed by a lethal dose of ether. The duodenum was also red and inflamed, and the heart contained black blood which was partly coagulated.

If the vapour of ether has been inhaled, a much smaller dose suffices to produce death than when liquid ether is swallowed. The symptoms and appearances of persons dying as a result of ether inhalation will differ according as the ether has caused respiratory or circulatory failure. In cases in which there is acute pulmonary œdema the lung symptoms will predominate, while cerebral hæmorrhage occurring under ether will give the characteristic symptoms associated with the brain lesion.

Post-mortem appearances.—If examined within twenty-four hours after death, the brain, lungs, liver, spleen, or kidneys, upon being cut, give a strong ethereal smell. The blood is dark and thick, although still fluid. The lungs are congested posteriorly, and filled with aerated spumous fluid in front (Taylor). The bronchial mucous membrane is reddened and injected throughout its entire extent. The cerebral and spinal vessels are found congested, and the meninges stained. If the ether has been administered by the bowel, the mucous membrane is darkly stained and the bowel may be distended and paralysed.

The detection of ether by analysis. — Ether in liquid may be distilled from the stomach contents, and led through a glass tube containing asbestos moistened by a mixture of sulphuric acid and saturated solution of bichromate of potash. The asbestos turns green.

Its odour is also characteristic ; ether burns with a smoky yellow flame ; it is only slightly soluble in water.

The tissues.—In recent examinations the odour is character-istic. Since but little ether is absorbed by the blood, and of this little some is converted into aldehyde (Taylor), it is almost impossible to separate ether by distillation from the blood or the solid tissues.

DEATH FROM POISONING BY CHLOROFORM.

This may occur through inhaling the vapour or drinking the fluid. In the latter case the individual, if examined before death, will be comatose, breathing stertorously, with slow, shallow respirations. The skin will be cold and blanched, the face livid, the lips ashen in hue, the pulse imperceptible, and the pupils may be widely dilated, but insensitive to light. Muscular flaccidity is present, but epileptiform convulsions often occur.

Post-mortem appearances.—In cases of death from chloro-form the appearances reported vary very much, and this is probably due to the confusion present in the minds of many persons concerning the connexion of cause and effect. Thus death from asphyxia, fear, shock, and so on, may be attributed to chloroform ; furthermore, the necropsies are seldom made soon enough to be of any value, while sufficient note is seldom taken of the degree of narcosis in which death occurred. We should expect the cadaveric appearances presented in the first degree of narcosis to differ widely from those found in later degrees, and yet in but few records have I been able to find any information bearing directly upon this point.

In the earlier degrees chloroform congests the vessels of the brain and cord, and so this condition, although inconstant, is sometimes found.

The lungs are usually deeply congested, the heart empty, flaccid, or containing a little fluid blood. In some cases the right heart is full, even to distension, of dark fluid blood (as-phyxia). The blood remains fluid, it is very dark, and is said occasionally to contain bubbles of gas (Taylor). Snow, ana-lysing thirty-four cases, describes visceral engorgement, but in some instances he found the lungs normal. Casper denies that any of the features pictured above are pathognomonic of chloroform poisoning. When the drug is swallowed it pro-duces gastro-enteritis, and pathological appearances resulting from this would be seen post mortem. The appearance of the

viscera in "delayed" chloroform poisoning (acidosis), as in the case of delayed ether poisoning, are not entirely characteristic, since similar appearances are found as the result of septic and other conditions. The liver, kidneys, and heart are often friable, the cells are fatty, and the gastro-intestinal tract is congested. Acetone, diacetic or β-oxybutyric acids may at times be recognised in the urine.

Detection of chloroform.—The odour very soon passes off. Dr. Taylor failed to detect any in the blood half an hour after administration. Analysis of the blood also fails to reveal any evidence after half an hour.

Analysis of the tissues.—The substance supposed to contain chloroform is placed in a flask, one end of which is in a hot-water bath, the other communicating with a tubulure which is heated by a flame. The bath is raised to 160° F., while the tube is heated to redness. Chloroform vapour driven off by the heat of the water-bath is split up as it traverses the tube, hydrochloric acid and chlorine being set free. The vapour reddens blue litmus, precipitates solutions of nitrate of silver, and liberates iodine from iodide of potassium, and this is tested in the usual way—with starch paper. The most accurate method of obtaining a quantitative analysis is that of the late Mr. A. Vernon Harcourt.*

Self-Indulgence in Anæsthetics.

A "habit" has been unhappily created for most forms of anæsthetics. Thus, some persons become addicted to self-administration of chloroform; some to that of ether; others, again, to that of chloral hydrate; while cocaine also has its victims. It is not within the scope of the present work to describe the proper modes of treating the slaves of this unfortunate vice, but merely to draw attention to it, that medico-legal questions arising out of such depraved practices may receive due notice. Nitrous oxide gas, although presenting greater difficulties in self-administration, has yet led some weak-principled persons to practise self-induction of anæsthesia by its aid.

The possibility of the subject of an inquiry—in any case of

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* See Report of Special Chloroform Commission, pp. 61 and 78.

supposed suicide or murder by anæsthetics—being an habitué
of one of them, should not be allowed to drop out of mind.

INSANITY FOLLOWING THE ADMINISTRATION OF ANÆSTHETICS.

Among persons predisposed to insanity the administration
of anæsthetics may, in certain rare cases, determine an attack
of mania. " It is the fact of the temporary disturbance of
function, and not the means by which this is produced, which
is of most importance " (Savage). It is stated, upon the high
authority of Sir George Savage, that chloroform, ether, nitrous
oxide gas, or indeed any anæsthetic, is capable of so interfering
with brain functions, that the delirium of commencing narcosis
may become reproduced upon the patient's recovering from
the sway of the anæsthetic, and may either persist as intrac-
table mania, or pass off after expending its violence in a sharp
but transient maniacal seizure. This liability was also noted
in 1865 by various speakers at the meeting of the Superinten-
dents of American Institutions for the Insane, at least as far
as chloroform and ether were concerned. The possibility of
such a result ensuing upon the administration of an anæsthetic
to a person either highly neurotic, or coming from a family in
which insanity has been developed, should be borne in mind
when such individuals are examined with a view to ascertain
their fitness for anæsthetisation. The suggestion that such
persons should be treated with spinal or local analgesia cannot
be considered satisfactory. Mania is recognised as a possible
result of these methods, and those who have had much experi-
ence warn us against employing them for neurotic and highly
nervous patients.

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